JUN 3 1932

S·A·E JOURNAL

JUNE 1932

CAR SALES MADE EASIER

by

CENTRIFUSE Brake Drums

Dealers and salesmen of 10 leading makes find Centrifuse Brake Drums—most vital brake improvement since the introduction of 4-wheel braking—a sale-deciding factor of the first order.

They find it pays them to emphasize in their sales work the greater dependability, easier control and constant brake safety that are built into—AND STAY WITH every car equipped with Centrifuse Brake Drums.

The more the prospects take increased power and speed of the new cars for granted, the keener, more natural, is their interest in new braking efficiency made necessary by changed driving standards—particularly free wheeling.

Ten car makers now use Centrifuse Brake Drums as standard equipment. If the make YOU sell is one of them, be sure to tell your prospects of the uniquely constructed Centrifuse that gives quicker, softer, surer, safer braking action, and keeps giving it, without adjustment, *more than 5 times longer!*

The story of the Centrifuse Brake Drum and its new and different efficiency is told in an illustrated booklet that should be read by every interested dealer and salesman. Write for a copy. It is free.

MOTOR WHEEL CORPORATION, Lansing, Michigan

Manufacturers of Demountable Wood, Steel and Wire Wheels . . . Forged Spoksteel Truck, Bus and Trailer Wheels . . . Stampings . . . *Sole Producers of* Centrifuse Brake Drums

S·A·E JOURNAL

Prepare for Prosperity!

Attend Six-Day Summer Meeting at White Sulphur Springs and Learn What Is New in the Industry!

WHEN the weather is stormy or otherwise unsuitable for fishing, the fisherman mends his nets. That is, the wise and provident fisherman does. His short-sighted neighbor lifts a mournful voice in lamentation and acts as if the rainy season were to be perpetual.

In a time of economic depression, when business activity seems to be at a standstill, the far-sighted man uses the present to prepare for the future.

An opportunity for the forward-looking automotive engineer to get ready for the days of prosperous activity that sooner or later are bound to come will be afforded this month by the Society's Summer Meeting, which will be held at White Sulphur Springs, W. Va., June 12 to 17. During those six busy days, 22 comprehensive and authoritative papers will be presented at 11 technical sessions, and the men attending those sessions will be enabled to obtain uptodate information about the newest developments in the various branches of the industry.

A Diversified Program

The program arranged by the Meetings Committee, under the chairmanship of Norman G. Shidle, and by the committees representing the various Professional Activities, is a varied one, designed to appeal to every member of the Society. Abstracts of the papers to be delivered are printed on the following page, and the complete program will be found on p. 13, facing the abstracts.

Some idea of the timely and informative nature of the material to be presented at the sessions can be obtained from reading the program and the abstracts, but no mere announcement can do justice to the excellence of the papers, addresses and discussion that the meeting will bring forth. A glance at the program and abstracts will, however, suffice to show each progressive member of the Society that a number of the items scheduled will be of intense interest to him; and a more careful scrutiny will make him realize that the 11 technical sessions contain numerous features that he actually cannot afford to miss.

Committee Meetings Important

Technical sessions are scheduled for each morning and evening. The Meetings Committee, when planning the meeting, left the afternoons open, to allow enough time for informal exchange of ideas and for the great amount of important business that must be transacted in the various committee meetings.

On behalf of the Meetings Committee, Chairman Shidle states that each session will begin exactly at the hour announced, so that ample time will be available for discussion, both formal and informal, after the papers have been presented.

An Accessible Location

For the majority of our members, White Sulphur Springs is very easy to reach. In most cases an overnight journey by rail is all that is required, and special railroad accommodations will be furnished on June 11 from New York City, West Philadelphia, Baltimore, City of Washington, Detroit, Cleveland and Toledo. The special cars will reach White Sulphur Springs on the morning of Sunday, June 12, in time for breakfast at the Greenbrier Hotel and a day of recreation before the serious business of the convention begins at the General Session that evening. Condensed railroad schedules for the special trains were enclosed with the program that was mailed to all members on May 20, together with the 1½-fare railroad certificates and directions for making Pullman reservations on the special trains.

For the return trip, the special trains will leave White Sulphur on Friday, June 17; those for Detroit and Cleveland at 5:55 p. m. and those for the East at 8:00 p. m., Eastern Standard Time. Members who attend the meeting are urged to make their return reservations early in the week. Dinner will be served at the Greenbrier on Friday evening at an early hour for the convenience of those departing by the special trains.

The many members who wish to drive to the meeting will find that excellent new roads offer them an ideal motor trip. They are advised to consult their local automobile club for maps and last-minute information regarding the roads.

When the programs and other mate-

(*Concluded on p. 19*)

Contents of Summer Meeting Papers

What Motor Cars Should Be.—Believing that tradition exerts an all too powerful influence on motor-car design, Mr. Stout, who is a "free thinker" along these lines, can be counted upon to suggest many new ideas concerning lighter and stronger structures, better body shapes and many other features that can profit by the application of the right sort of practical imagination. Mr. Stout's points on design will be intermingled with a wealth of refreshing engineering philosophy.

Use of Trailers with Motor-Trucks.—A comprehensive discussion of the general use of trailers and semi-trailers in both intrastate and interstate transportation.

Piston-Ring Progress.—This paper brings to the attention of the industry new gages and test apparatus by which piston-ring performance can be predetermined. A radial-pressure scale that measures the actual resultant pressure exerted on the cylinder wall by a piston-ring, and a roller gage that enables one to feel with his fingers the pressure exerted on the wall at 17 points around its entire circumference, will be exhibited at the meeting and featured in the paper.

Frame Design with Reference to Car Stability.—The limitations of both flexible and rigid frames are considered.

Power Brakes for Trucks and Trailers—Air Type.—Component parts of the air-brake system are described, and considerable emphasis is laid upon the automatic feature of the trailer equipment that applies the brakes in case of a break-in-two. A scheme for independent control of trailers and another automatic emergency scheme for trucks are described.

Power Brakes for Trucks and Trailers—Vacuum Type.—The author of this paper does not attempt to cover all the forms and types of vacuum-operated brake but concentrates on the installation and hookups to tractors and trailers, and the boosters and valves used.

What Can Be Seen with Headlights.—A report of research, conducted under actual operating conditions, indicating quantitatively the effect and interrelation of the most important variables on the visibility of the roadway and objects upon it.

Development of Fixed-Focus Headlighting Equipment.—The whys and wherefores of fixed-focus head-lamps. A critical technical analysis of this Country's prevailing type of lighting equipment.

Free-Wheeling Devices and Control.—After defining free-wheeling and discussing various types of free-wheeling device, the author describes the design of various parts of the roller-ratchet type and the design of a coil-spring type, and discusses the metallurgical consideration of the different parts, lubrication requirements and limitations, control mechanisms, general design of the free-wheel unit in relation to the transmission and possible future developments.

Brake-Drum Metallurgy.—The author asserts that grain structures desirable for the braking surfaces of drums can be obtained by certain methods of manufacture regardless of the particular design employed. His paper, illustrated by micro-photographs, discusses the different kinds of wear found on braking surfaces and points out the importance of maintaining careful control of material, processes and temperatures in the manufacture of drums.

Brake-Lining Problems.—In an authoritative technical paper, the author gives an impartial view of the various factors involved in brake-lining problems.

Where Do We Go from Here?—Where we have been, and the reasons for the progress made in automobile design, manufacture and sale. Where we are going from here, and how experience points the way to possible future developments.

Engineering Application Relative to Automotive-Body Die Development.—The value of engineering in the development of the automobile-body die industry. Past and present problems, as well as those of the future.

Doughnut Tires—The paper discusses punctures, blowouts, air pressures, wheel and tire weights, jacks, brakes, safety, rideability, roadability and maneuverability of super-balloon tires.

Application of Aerodynamics to the Present Automobile.—Stating that good airplane practice is not necessarily good automobile practice, the author presents the exact results of recently finished extensive aerodynamic studies of automobiles. Among other interesting facts, he explains why, for least resistance, the motor-car should not have the maximum cross-section one-third of its length back from the front.

Ignition Quality of Diesel Fuels as Governed by Thermal Stability and Expressed in Cetene Numbers.—The method of determining the ignition quality of Diesel fuels in terms of cetene numbers as used for routine work is described. Cetene numbers of Diesel fuels are comparable with octane numbers of gasolines. Correlation with different engines and different methods is shown, and the influence of viscosity, temperature, load and the like is discussed. Thermal stability and not the oxidizing tendency is shown to be the deciding factor in ignition quality. Ignition and combustion processes are analyzed on the basis of typical engine diagrams and the relative importance of ignition quality as a fuel characteristic and the guiding principles for designing engines are presented.

Vapor Pressures of Automotive Diesel Fuels.—From vapor-pressure measurements made on approximately 20 distillate fuel-oils over a wide temperature range in each case, the conclusion is drawn that vapor pressures can be estimated from distillation data and hence it is possible to determine from the data how high the oil may be heated without encountering vapor lock in Diesel-fuel feed systems.

Design Factors and Combustion Control Determine Future of Automotive Diesels.—The author tells how factors in design govern the commercial acceptability of the high-speed Diesel engine and places special emphasis on combustion control through the medium of the after-chamber.

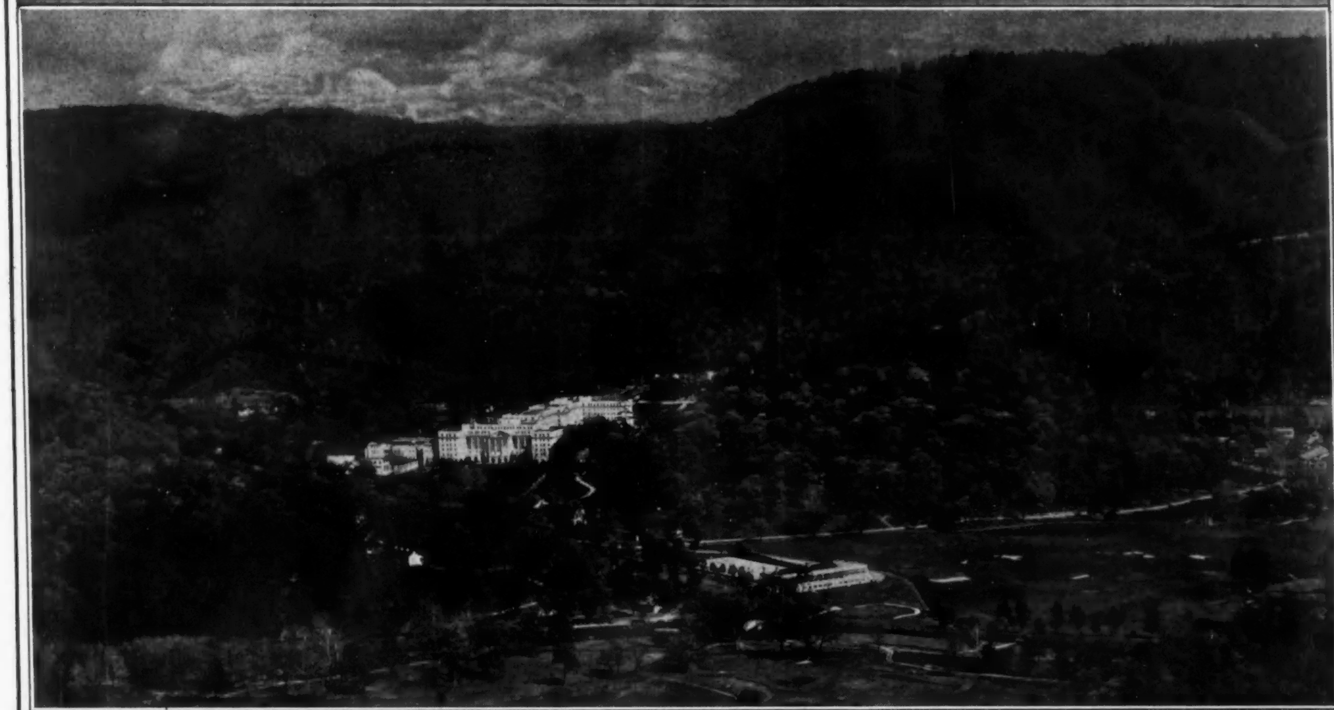
Highways of the Skies Linking the Americas.—A picturesque, graphic story of the problems involved in the establishment of international air transportation in South America and the West Indies. Illustrated by motion-pictures with sound.

Journal-Bearing Characteristics in the Region of Thin-Film Lubrication.—This paper covers an extension of lubrication research into the region of thin-film lubrication where the bearing is operating under unstable conditions. The results indicate that, in this region, bearing friction, and hence the heat developed, is not a function of ZN/P but is dependent also upon the particular values of the operating variables. A comparison of the running-in characteristics of babbitt metal and bronze is also included.

Effect of Temperature on the Determination of Gum in Gasoline.—Dealing with the effect of temperature of evaporation on the measured gum-contents, this paper shows that the measured gum-content becomes less as the temperature of evaporation is increased but that the relative gum-contents of a series of gasolines are independent of the temperature of evaporation. Accordingly, any convenient volume of gasoline and any convenient temperature can be employed for the determination of gum contents. Further, the relative values thus obtained should correspond closely with the relative weights of gum deposited in the engine manifold by these gasolines.

Effect of Humidity on Engine Performance.—That atmospheric humidity has an effect on engine power has been recognized for some time but some doubt existed for a time as to whether the effects observed were proportional to the relative or to the absolute humidity. A series of tests made in an unusual way decided this point conclusively. These tests and others augmenting the range of conditions and the factors covered are discussed. Since variation of humidity affects power to an extent roughly equal to that resulting from barometric variation, the results of automotive-engine tests should be corrected to standard dry-air conditions, as is already done in the case of aircraft engines.

SUMMER MEETING PROGRAM



WHITE SULPHUR SPRINGS, W. VA. ~ JUNE 12 TO 17

Sunday, June 12

General Session—8:30 P. M.

What Motor Cars Should Be—W. B. Stout, Stout Engineering Laboratories, Inc.

Monday, June 13

Transportation and Maintenance Session
10:00 A. M.

Use of Trailers with Motor-Trucks—J. W. Cottrell, Chilton Class Journal Co.

Engine and Frame Session—8:30 P. M.

Piston-Ring Progress—R. R. Teetor and H. M. Bramberry, Perfect Circle Co.

Frame Design with Reference to Car Stability—C. R. Paton, Packard Motor Car Co.

Tuesday, June 14

Motor-Truck and Motorcoach Session—10:00 A. M.

Power Brakes for Trucks and Trailers—Air Type—S. Johnson, Jr., Bendix-Westinghouse Automotive Air Brake Co.

Power Brakes for Trucks and Trailers—Vacuum Type—R. P. Breese, Bragg-Kliesrath Corp.

Semi-Annual Business Session—8:30 P. M.

President A. J. Scaife in the Chair

Headlight Session

What Can Be Seen with Headlights—H. C. Dickinson, Bureau of Standards

Development of Fixed-Focus Headlighting Equipment—R. N. Falge, General Motors Corp., and W. C. Brown, General Electric Co.

Wednesday, June 15

Chassis Session—10:00 A. M.

Free-Wheeling Devices and Control—A. M. Wolf, Consulting Engineer

Brake-Drum Metallurgy—F. L. Main, Kelsey-Hayes Wheel Corp.

Brake-Lining Problems—Chris Bockius, Raybestos-Manhattan, Inc.

Body Session—8:30 P. M.

Where Do We Go from Here?—F. S. Spring, Hudson Motor Car Co.

Engineering Application Relative to Automotive-Body Die Development—F. L. Frailich, Briggs Mfg. Co.

Thursday, June 16

Future Development Session—10:00 A. M.

Doughnut Tires—B. J. Lemon, United States Rubber Co.

Application of Aerodynamics to the Present Motor-Car—H. G. Winter, Briggs Mfg. Co.

Diesel Engine Session—10:00 A. M.

Ignition Quality of Diesel Fuels as Governed by Thermal Stability—G. D. Boerlage and J. J. Broeze, Bataafsche Petroleum Co., Delft, Holland.

Vapor Pressures of Automotive Diesel Fuels—E. W. Aldrich, Bureau of Standards

Design Factors and Combustion Control Determine Future of Automotive Diesels—R. P. Ramsey, Buda Co.

Aircraft Session—8:30 P. M.

Highways of the Skies Linking the Americas—V. E. Chenea, Pan-American Airways System

Friday, June 17

Research Session—10:00 A. M.

Journal-Bearing Characteristics in the Region of Thin-Film Lubrication—S. A. McKee and T. R. McKee, Bureau of Standards

Effect of Temperature on the Determination of Gum in Gasoline—O. C. Bridgeman and J. C. Molitor, Bureau of Standards

Effect of Humidity on Engine Performance—H. H. Allen and D. B. Brooks, Bureau of Standards.

Philadelphia Still Leads!

Northwest Section Jumps from Sixth to Second Place in Get-Your-Man Campaign

THE Philadelphia Section still remains the early bird and to date still has the worm. Since the May issue of THE JOURNAL, a number of gains have been made by other Sections, with the result that they have stepped up over some of their nearest competitors.

The race for second place took on a decidedly new turn when the Northwest Section jumped from sixth place as shown in the May issue of THE JOURNAL to second place on May 23, bettering the percentages made by the Indiana and the Canadian Sections.

With two months more to go and continued activity on the part of the Section organizations, it is probable that still more surprising changes will be recorded before the final result is announced.

President Scaife Asks Cooperation

Already, the returns assure the Get-Your-Man campaign of reasonable success, *but this is not enough. The results must be outstanding. Every member get a member* and another high record of accomplishment will be added to the many that have been achieved by S.A.E. workers through the medium of their professional society.

Our President, Mr. Scaife, has brought in several fine engineers, so in asking each S.A.E. enthusiast to *get one member* he knows that it can be done and done easily.

Section Standing, May 23

Place	Section	Applications, Per Cent of Quota
1	Philadelphia	54.3
2	Northwest	37.5
3	Indiana	35.7
4	Canadian	34.5
5	Kansas City	26.2
6	Baltimore	24.3
7	Chicago	18.9
8	Detroit	16.1
9	Pittsburgh	15.1
10	So. California	15.0
11	Metropolitan	14.1
12	Syracuse	12.1
13	Wichita	11.8
14	St. Louis	9.7
15	Milwaukee	8.3
16	Dayton	8.1
17	No. California	8.0
18	Washington	7.0
19	New England	6.0
20	Cleveland	5.8
21	Buffalo	3.9
22	Oregon	0.0

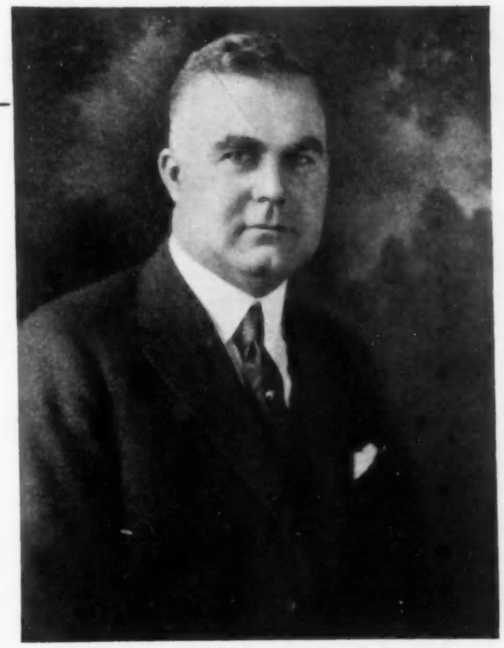
Helps Available to Members

An attractive booklet that tells the story of Society activities and advantages is available to any member or prospective member who cares to ask for it. Answering the questions, Why? What? Who? and How?, this 20-page illustrated publication should be read by every member and passed along to a likely prospect. *Write and request a copy now.*

The Journal, S.A.E. Handbook, Transactions and Roster have been used to good advantage by those who have shown others why the S.A.E. badge is the true *Hallmark of Automotive Engineering.*

Chairman Alex Taub and his Membership Committee are eager to be of assistance; they promise to give prompt attention to requests for information or help along membership lines which may be sent to the Society's Headquarters.

Fred Zeder Calls for Engineering Courage



Vice-President in charge of Engineering,
The Chrysler Corporation

Fellow S.A.E. Members:

COUNTLESS developments in our industry have clearly demonstrated the importance of engineering leadership. In fact, the phenomenal progress of automotive enterprise has been largely based upon the accomplishments of our profession. With these facts in mind, it is astonishing that engineering effort has not been more fully appreciated.

For this state of affairs, engineers themselves are largely responsible. Strangely enough, many members of our profession have not begun to realize that their position is strategic, both industrially and commercially. Too many are still tolerant of the attitude that an engineer can be nothing more than a blue-print specialist whose talent is to be considered in the nature of a commodity. It is high time for engineers to assert themselves more definitely. They must seek opportunities to demonstrate the value of exact processes of reasoning when applied to the commercial phases of our industry. More engineering thinking is needed in business, and more business thinking is needed in engineering.

No higher profession exists than engineering, but it is the engineer's responsibility to maintain the high standards of this profession by developing to the utmost his natural attributes of logical analysis, originality and skill. The greatest rewards, both tangible and intangible, will go to those engineers who exercise virile courage and breadth of vision in applying their services most effectively toward the general advancement of our industry.

Cordially yours,

Fred M. Zeder

Chronicle and Comment

The S.A.E. Staff AS A GUIDE to all who have occasion to communicate with members of the Society's headquarters staff in New York City, the following listing of personnel is offered:

Secretary and General Manager
John A. C. Warner

Assistant to the General Manager
C. B. Whittelsey, Jr.

Staff contact with Passenger-Car Body Activity and with Finance Committee. Office management, advertising and publicity.

Manager, Research Department
C. B. Veal

Staff contact with Research Committee and related groups; also with Meetings Committee and Passenger-Car Activity.

Manager, Standards Department
R. S. Burnett

Staff contact with Standards Committee and Divisions; also with Production, Motorcoach and Motor-Truck and Transportation and Maintenance Activities.

Manager, Sections Department
A. J. Underwood

Staff contact with Sections Committee; also with Aircraft, Aircraft-Engine and Diesel-Engine Activities.

Manager, Editorial Department
H. W. Perry

Staff contact with Publication Committee. Journal Editorial Department management.

The office of Assistant General Manager was recently declared vacant by the Council.

Every Member Get a Member! THUS FAR, the Society's membership activities that began four months ago under the slogan "Get Your Man" have shown good results, especially in view of present conditions. A number of our Sections have recorded very creditable achievements in this cooperative effort, which of course means that many members have brought in new members.

However, if the enterprise is to be outstandingly successful, *you as an individual member must take unto yourself the agreeable duty of "exposing" one qualified person to the advantages that the Society offers.* Very little thought and individual effort are required to make a dignified presentation of the benefits of membership.

Booklets, application blanks and other literature are available for the asking.

And Philadelphia Still Leads FROM the City of Brotherly Love comes a steady flow of applications, indicating the interest and loyalty of this group of members and their belief in the advantages and future of their Section and the Society.

Philadelphia has obtained applications totaling more than 50 per cent of its quota! Such activity should provide the inspiration to every member to do his part in this membership work and the incentive for every other Section to equal this splendid record.

A Superior Program for White Sulphur Meeting UNDER the general guidance of the Meetings Committee, of which Norman G. Shidle is Chairman, the Society's various Activities have designed and constructed a Summer Meeting program that has enough superior features to attract every progressive engineer who can possibly come to White Sulphur Springs this month. A program of the meeting, together with abstracts of the papers, will be found on pp. 12 and 13 of this issue of THE JOURNAL.

Kettering Praises S.A.E. Spirit IN THE COURSE of a magnificent address, presented at the May 9 meeting of the Detroit Section, C. F. Kettering expressed his belief that the world is suffering, not from over-mechanization, but from over-exploitation. He believes that little if any responsibility for depressed economic conditions should be placed upon the shoulders of engineers. He said that he felt, however, very strongly that engineers, with their precise methods of thinking, can be counted upon very heavily to correct present weaknesses in our economic system.

It was particularly pleasing to have Mr. Kettering remark upon the splendid fellowship that exists in the Society of Automotive Engineers and in the automotive business generally, a situation that he believed does not prevail to as high a degree in other competitive businesses.

New Standards Committee Procedure INSTEAD of holding the general Standards Committee sessions as heretofore at the Annual and Summer Meetings of the Society, all reports of Divisions submitted for adoption will be considered and passed upon by the Standards Committee, composed of the Chairmen of the respective Divisions or their delegated representatives, under the new procedure approved in principle by the Council of the Society at the Annual Meeting last January. The action taken by the Standards Committee on the Division reports will be referred to the Council as heretofore and reported in the account of the Summer Meeting of the Society in the July issue of THE JOURNAL.

S.A.E. Automotive-Transport-Code Committee ALL ACTIVITIES within the Society relating to motor-vehicle transportation codes and regulations have been assigned by the Council to the Automotive-Transport-Code Committee that was organized this year. Heretofore this work was assigned to subcommittees appointed under the Transportation and Maintenance Activity and the Motorcoach and Motor-Truck Activity and a special committee that had been appointed to cooperate with the Motor-Vehicle Conference Committee in revisions of the uniform motorcoach code that was sponsored by the M.V.C.C. at a general conference in the City of Washington three years ago.

The Society announces that F. K. Glynn, who was Vice-President of the Transportation and Maintenance Activity last year, has been appointed Chairman of the Code Committee.

Appraising Diesel Engines by Air Capacity and Speed

Annual Meeting Paper

By Julius Kuttner[1]

BRAKE mean effective pressure is held by the author to be inadequate as a measure of Diesel-engine capacity, because it fails to distinguish between losses in capacity that are chargeable to low volumetric efficiency and losses resulting from imperfections in combustion. A study of air capacities assists in making this essential distinction and is advocated as a better basis for appraisal. Variation in effective air supply with speed is regarded as especially important, as acceleration and peak power depend on it.

Experimental work cited had to do mainly with the determination of the percentage of carbon dioxide in the exhaust gas, and this is used as a basis for calculating the quantity of air passing through the engine. Conclusions are drawn also from some experiments in which the intake air was measured directly by an orifice-type meter.

An excess-air coefficient is set up as the ratio between the quantity of air actually passing through the engine and that theoretically required for the work done, on the assumption that combustion conforms to the theoretical mixed-pressure cycle. This coefficient is said to register directly the engine's ability to produce power from fuel, and its variation with engine speed is regarded as of paramount importance in evaluating an engine for automotive propulsion and thus reducing the commercial hazard of launching a new type of engine.

Discussers give more attention to engine design than to the method of evaluation, some advocating the undivided combustion chamber, rather than the divided which was used in two of the tests reported, and others questioning the author's assumptions on stroke-bore ratio. One discusser presents a scale for measuring the smokiness of the exhaust and another reports an arrangement of injection valves that is said to make the turbulence in an antechamber engine more uniform.

EVER-INCREASING sums of money are being spent to find out what commercial possibilities lie ahead of the automotive Diesel engine and to determine, if possible, which of the now competing Diesel-engine systems have the greater prospect for survival. Hence asking whether this increasing investment of capital is fully protected against possible errors in the technique of appraising the comparative merits of these engines becomes pertinent.

Such appraisals usually are made on the basis of well-known rating factors such as torque and specific capacity, which, while they involve no inherent error, fail to give a complete commercial picture of the Diesel engine in question. Both technical thoroughness and business prudence make necessary going behind these figures and appraising Diesel engines against the yardstick of fundamental physics and chemistry that underlie the performance of all internal-combustion engines. Essentially, these are the processes of mixing and combining fuel and air in the engine cylinder, whereas manifestations such as mean pressure and power are only secondary. Particularly, the ability to make good use of displaced air is at the focal point of most of the technical problems of the Diesel engine, and the returns that are to be yielded by investments in Diesel research depend largely upon the analysis of this point.

Budget for Air Supply

Recognizing that the cubic displacement of a Diesel engine is the principal factor governing its weight, cost and applicability to vehicles of various classes, the skeleton of a budget for capacity has been drawn up and is shown in Table 1.

TABLE 1—BUDGET FOR AIR SUPPLY OF AN AUTOMOTIVE DIESEL ENGINE

Credit	Debit
	Effect of High Compression-Ratio
	(1) Dimensional Loss
Displacement with bore and stroke equal and zero volumetric losses	Engines having a stroke-bore ratio of unity are not likely to be practical, and allowance must be made, at fixed values of air speed through valves and fixed ratios of valve area to piston area, for a loss corresponding to the excess of stroke-bore ratio over unity.
	(2) Pocketing Loss
	The application of valves of adequate size to small combustion chambers leads to the formation of pockets containing compressed air that does not participate effectively in combustion.
	(3) Volumetric Loss
	Volumetric loss is often increased by the difficulty of fitting adequately large valves to small combustion chambers.
	Incomplete Combustion
	(1) Deficient Turbulence
	(*a*) At all speeds (Plain, undivided combustion chamber)
	(*b*) At low speeds (Subdivided chamber and simple chamber with turbulence induced during suction)
	(2) Deficient Compression
	(*a*) Designed ratio insufficient
	(*b*) Effective ratio diminished by volumetric phenomena
	(*aa*) Reduction in compression temperature
	(*bb*) Reduction in density

To give several illustrations of appraising the automotive serviceability of Diesel engines on the basis of air capacity, experimental data have been utilized from tests on three Diesel engines as follows:

(1) A single-cylinder open-chamber engine of the Hesselman type with a shrouded inlet valve, reported by Fritz Schmidt[2]

(2) A six-cylinder Oberhaensli automotive engine, reported by Dr. S. J. Davies[3]

(3) A four-cylinder Oberhaensli engine tested by the International Motor Co. under the direction of V. C. Young

[1] Consulting engineer, New York City.

[2] See *Zeitschrift des Vereines Deutscher Ingenieure*, Aug. 16, 1930, p. 1151.

[3] See *The Engineer*, Oct. 16, 1931, p. 414.

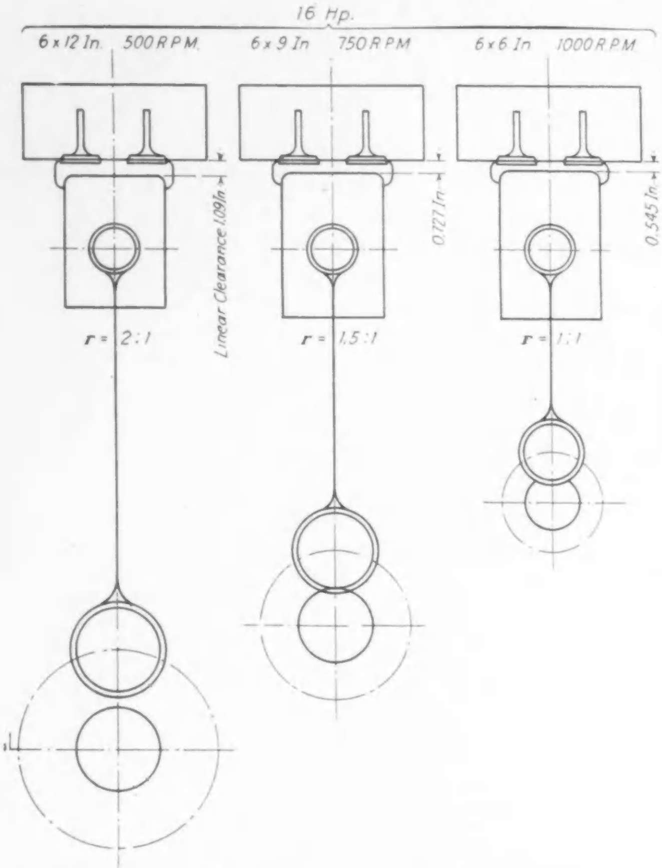


FIG. 1—EFFECT OF STROKE-BORE RATIO WITH CONSTANT PISTON SPEED

Although the single-cylinder machine with 8.27-in. bore and 11.8-in. stroke would hardly be considered automotive, the tests are unusual because a speed range of from 45 per cent to full speed is covered thoroughly and the air capacity was checked in three ways: by air-meter, by chemical calculations based on inlet air and by chemical calculations based on exhaust-gas analysis.

The six-cylinder engine was tested by air-meter before its development had been fully completed, and the results give an opportunity for studying deficiencies that were removed later.

The four-cylinder engine was tested by exhaust-gas analysis after it had been fully developed for commercial purposes.

Principal emphasis is to be laid on the distinction between capacity losses, including pocketing of air in crannies of the combustion space which are chargeable to the combustion process itself, and losses of air occurring before the compression stroke begins.

The Stroke-Bore Ratio

Losses in specific capacity due to the use of high stroke-bore ratios, with associated low engine speeds for constant air speed past the inlet valve, are well known. The attempt to use short ratios for Diesel engines seriously decreases the size of the combustion chamber which is already small because of the high compression-ratio. A graphical indication of this influence is given in Fig. 1, which shows a series of hypothetical engines in which the mean piston speed, brake mean effective pressure and air speed through valves are kept constant by varying inversely the stroke and rotative speed while the stroke-bore ratio is taken as 2, 1.5 and 1 to 1. The appreciable difference in engine size for an unchanging output of 16 hp. is apparent, but possibly the most significant fact is that the height of the combustion chamber, assumed to be a disc of the same diameter as the cylinder, varies directly as the stroke-bore ratio. When this is equal to 1, the chamber becomes so flat as to inhibit the combustion of a liquid-fuel spray under all but certain exceptional conditions. Another way of reaching the same conclusion may be shown by the formula

$$\text{Hp.} = \frac{pv^3}{2330\ n^2\ r^2} \qquad (1)$$

which gives the output in terms of the brake mean effective pressure, the piston speed, the revolutions per minute and r, the stroke-bore ratio. According to this, very large capacities per cylinder could be obtained by merely reducing the value of r, but the resulting contours of the combustion space would then be more difficult to utilize for Diesel combustion.

Fig. 2 shows the exceptional case of a Diesel engine having its stroke-bore ratio 0.936, less than unity. It is an M.A.N. submarine Diesel engine of 16.55-in. stroke and 17.70-in. bore, in which the disadvantages of an excessively flat combustion space are offset by using duplicate air-injection fuel-valves. That the best modern airless-injection practice will ever be able to approach the efficiency of the dual air sprays is not considered likely, and for practical purposes not even unity stroke-bore ratio can be approached in high-speed airless-injection automotive Diesel engines unless supercharging is employed. As far as is now known, it will be safe to neglect stroke-bore ratios smaller than 1.3. The Packard airplane Diesel engine has a ratio of 1.25, and that probably is among the causes of some inadequacies in its performance.

Fig. 3 shows a Lanova automotive engine for which unusually high combustion efficiency is claimed, exceeding 91 per cent for the ratio of consumed air to available air. However, this advantage is paid for in terms of an excessively high stroke-bore ratio, 2.15:1, which limits the maximum rotative speed of the engine of only 3-in. bore to 1400 r.p.m.

Valve Area

According to Formula (1), large increases in capacity could also be obtained by increasing v, the mean piston speed, and using valves large enough to keep the air speed constant, say at 15,000 ft. per min. Fig. 4 gives an indication of what this might lead to, assuming the use of a combustion chamber of the undivided type with a reasonably good concentration of volume. However, providing systematic turbulence in any of the combustion chambers sketched in Fig. 4, is not easy, and those with oblique valve spindles would be subject to manufacturing objections. The smallest one shown, having valve spindles parallel to the cylinder center-line, probably is the easiest to manufacture, and, as will be shown later, it permits subdividing the chamber more readily than do the arrangements with larger valves. Such subdivision appears essential for good turbulence and associated high brake mean effective pressure at low rotative speeds, which are of obvious importance from the automotive viewpoint.

At speeds lower than those corresponding to peak torque, the quantity of fuel that can be smokelessly consumed decreases in relation to the available air. The accompanying loss in torque varies markedly from one Diesel-engine system to another, generally being more pronounced in engines with open chambers than in those having subdivided chambers. As the speed falls off, the induced turbulence decreases, usually with a marked loss in the capacity of the air for uniting with the fuel. This effect is so pronounced in some engines that they cannot be idled on all cylinders, some of which

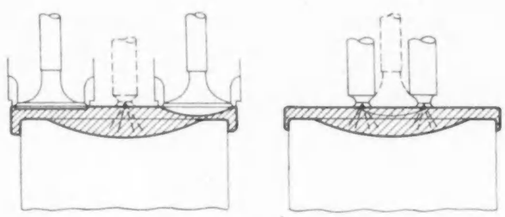


FIG. 2

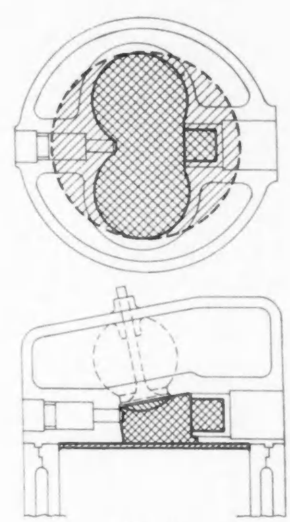


FIG. 3

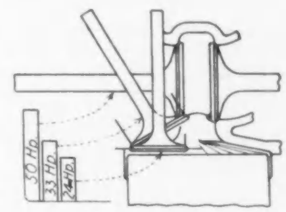


FIG. 4

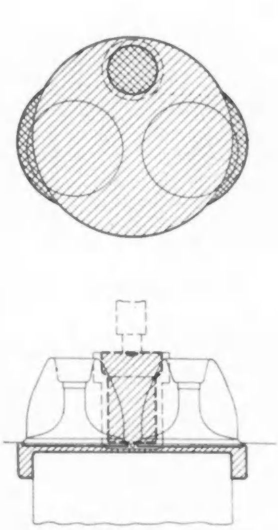


FIG. 5

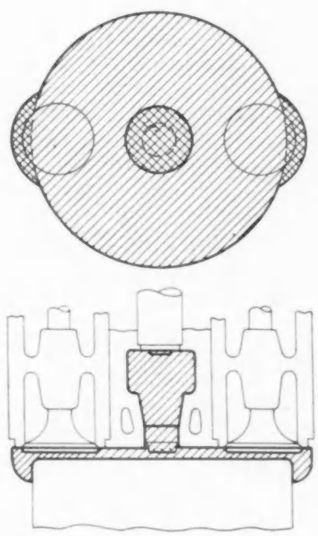


FIG. 6

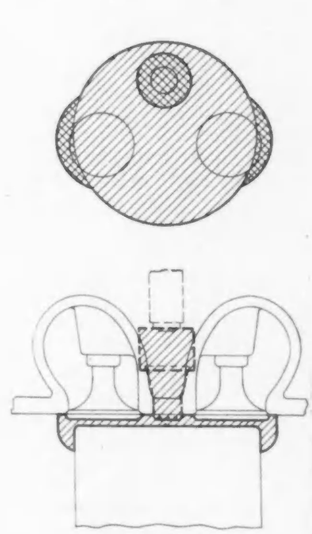


FIG. 7

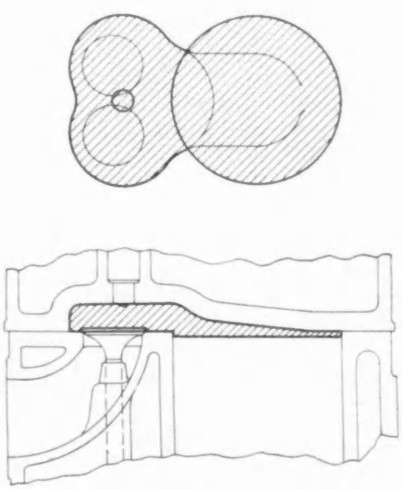


FIG. 8

Fig. 2—M.A.N. Dual-Valve Air-Injection Engine; $r = 0.936$

Fig. 3—Lanova Automotive Engine; $b = 0.25$, $r \approx 2.15$

Fig. 4—Arrangements Possible with Various Sizes of Valve

Fig. 5—Engine with Large Valves and Offset Precombustion Chamber; $b \approx 0.485$

Fig. 6—MWM-Benz, Having Central Precombustion Chamber; $b = 0.26$, $r = 1.57$

Fig. 7—Engine with Small Valves and Offset Precombustion Chamber; $b = 0.372$, $r = 1.574$

Fig. 8—Waukesha L-Head Engine; $b \approx 0.35$

Fig. 9—Oberhaensli Engine with Spherical Auxiliary Chamber; $b = 0.4$, $r = 1.38$

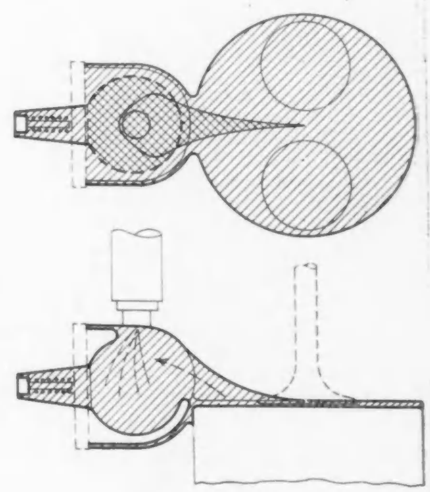


FIG. 9

COMBUSTION CHAMBERS OF VARIOUS ENGINES

must be cut out entirely to permit idling at acceptably low speeds. Naturally, the pick-up of such engines is also deficient, not because the quantity of air present in the cylinders is small but because of failure of the combustion system to make effective use of the available air.

Dead Pockets

The extremely brief time available for the formation of an air-fuel mixture in a Diesel engine is responsible for waste of air that is pocketed in inaccessible crannies of the combustion spaces. The high compression-ratio of the Diesel engine, with resulting small combustion-chamber volume, increases the percentage effect of the pocketed air.

Fig. 5 shows a typical precombustion-chamber Diesel engine having overhead valves with parallel spindles and a port diameter greater than 0.4 of the bore. To accommodate valves of this extra large size, valve pockets that are large enough to provide mechanical clearance around the valve heads at full lift and to assure free flow of air or gases must be milled in the upper end of the cylinder bore. The air caught in the pockets is largely unavailable at the moment of injection and combustion, and this for all practical purposes offsets the gain in volumetric efficiency resulting from the greater size of the valves. Although the air capacity of this design would show high values, the combustion efficiency suffers from pocketing, illustrating the typical Diesel-engine problem arising out of the conflict between valve arrangement and combustion-space contour.

A centrally located combustion chamber, such as that shown in Fig. 6, necessitates smaller valves than can be used with a chamber located at one side (Fig. 7), but it probably distributes the fuel more effectively. With equal valve sizes, the offset location of the chamber permits making the engine smaller and running it at higher speed, assuming equal air velocity; but the full increase in specific capacity probably will not be realized, because a greater proportion of the air will become unavailable for combustion purposes.

Diesel engines of the L-head type are subject to analogous limitations of valve size, because the larger they are made the farther must their clearance spaces be extended out to one side. This extension of the combustion space is difficult to reconcile with the requirements imposed by a high compression-ratio; if the volume above the valves is sufficiently reduced, the free flow to and from the valves, and even their lift, may be restricted. At the same time, the resulting contour can hardly be considered to be ideal for a combustion space in which to distribute and burn a jet of liquid-fuel droplets whose impingement on metallic surfaces does not lead to the best results. Partially offsetting this may be the hot-spot action of the exhaust-valve head, but so far as is known no commercially significant results have been obtained by taking advantage of this feature. In some cases an attempt has been made to give a suitable contour to the throat or passage connecting the space above the valve deck with the cylinder, as illustrated in Fig. 8, but such efforts must be limited because the valves, rather than combustion requirements, control the arrangement of the clearance space. The L-head Diesel engine has an undeniable advantage in low manufacturing cost, but the advantage seems to

Symbols Used in This Paper

A = volume of air at atmospheric pressure and 80 deg. fahr. passing through the engine, cubic feet per hour.

a = volume of air at atmospheric pressure and 32 deg. fahr. theoretically necessary for complete combustion of 1 lb. of fuel, pounds

b = ratio between effective valve diameter and cylinder bore

C_v = specific heat of air at constant volume, taken as 0.169 B.t.u. per lb. per deg. fahr.

c = weight of carbon per pound of fuel, pounds

D = content of CO_2 gas by volume contained in the exhaust gases before water vapor is condensed out, decimal fraction

d = content of CO_2 gas by volume contained in the exhaust gases after water vapor is condensed out, decimal fraction

E = net-air coefficient, or ratio between theoretically necessary air and displacement.

e = volumetric efficiency, or ratio between air actually available and piston displacement

F = quantity of fuel supplied, pounds per hour

H = lower heat value of 1 lb. of fuel, British thermal units

h = weight of hydrogen per pound of fuel, pounds

j = excess-air coefficient, computed from the quantity of fuel supplied

k = mean adiabatic exponent, taken as 1.35

M = mol constant, 358.7

n = engine speed, revolutions per minute

P = mean indicated pressure, pounds per square inch

p = brake mean effective pressure, pounds per square inch

p_1, p_2, etc. = absolute pressure at correspondingly numbered points on the diagram in Fig. 16, pounds per square inch

Q_0 = total input of heat, British thermal units, input of heat from combustion of fuel

Q_1 = heat input from combustion at constant volume, British thermal units (Fig. 16)

Q_2 = heat input from combustion at constant pressure, British thermal units (Fig. 16)

Q_d = heat required to fill card to cut-off point x, shown in Fig. 16

Q_f = heat that would be liberated if all the air in the cylinder were consumed, British thermal units

r = stroke-bore ratio

T = temperature, absolute degrees fahrenheit. Subscript figures represent corresponding points on Fig. 16

U = combustion coefficient, ratio of the volume of air theoretically necessary for combustion to the piston displacement less the volumetric loss

u = efficiency of air utilization, or Q_d/Q_f

V = piston displacement of engine, cubic feet

V_c = clearance volume of cylinder, cubic feet

v = piston speed, feet per minute

w = firing ratio, or ratio between absolute firing pressure and absolute compression pressure

x = cut-off ratio, or ratio of volume of cylinder with piston at cut-off position to volume of clearance space

y = volume of cylinder with piston at the point at which the fuel supply is cut off

z = compression ratio, or ratio of total cylinder volume including clearance space to volume of clearance space

be an illusory one if the engine as a whole must be made larger as the result of deficient action.

Fig. 9 shows the valve arrangement and combustion chamber of the Oberhaensli engines to which reference has already been made in connection with tests for air capacity. The stroke-bore ratio of the four-cylinder unit

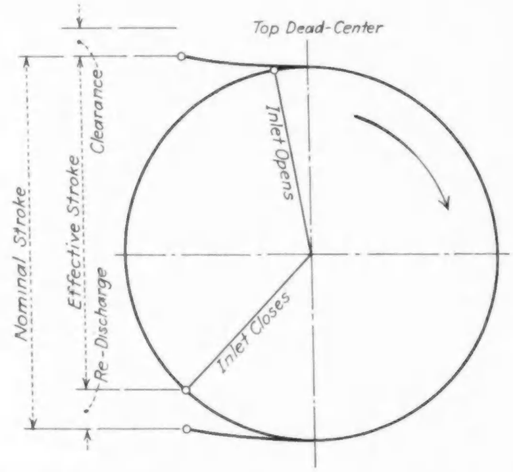


FIG. 10—DIAGRAM SHOWING EFFECTIVE STROKE WITH LATE CLOSING OF INLET VALVE

The Compression Ratio Is 13.8, Based on the Nominal Stroke, and 12.4, Based on the Effective Stroke

is 1.385, and the ratio of effective valve diameter to cylinder bore is 0.4, which corresponds to maximum air speed of about 15,000 ft. per min. The shape of the auxiliary chamber is spherical, and the fairly large connecting passage between it and the cylinder is streamlined to induce as much turbulence as possible in the sphere. Neither the design nor the proportions of the chamber are related to the valve size, the latter being made as large as possible without pockets in the upper end of the cylinder bore and without sacrificing good water-cooling at the point where the valve passages intersect the roof of the combustion chamber. The actual pocketing is limited to the mechanical clearance directly above the piston crown and to the interstices between the combustion shell and its pocket. Although the side location of the chamber might lead to distribution difficulties, these are likely to be offset by the good concentration of air resulting from the spherical contour of the chamber and from the large size of the passage. The latter is formed so as to direct the surge of burning mixture issuing from the chamber to distribute it well across the entire cylinder bore.

Volumetric Efficiency

As problems in volumetric efficiency are essentially common to both Diesel and gasoline engines, a reconsideration of the data from past research on this subject is unnecessary. They relate principally to the orifice characteristics of poppet valves and to velocities of approach in intake passages. Generally speaking, the Diesel engine has an advantage over the gasoline engine because it works without a carbureter and is therefore free from the volumetric losses inherent in the operation of this device.

Contraction losses at the edge of the inlet port at the side of the cylinder, however, may be considerable. A Diesel engine recently tested showed approximately 5 per cent more power at full load when operated with an inlet manifold than when the air had to pass the sharp edges of the ports. The manifold apparently has the effect of diminishing eddy-current losses in the inlet-air column, and this might profitably be taken into account when Diesel-engine inlet-manifolds are being designed. In some cases attention is paid only to silencing the intake and providing for air filtration, but improvements in volumetric efficiency due to careful inlet-manifold design are substantial enough to justify consideration.

Volumetric efficiency as a function of engine speed is influenced also by the inlet-valve timing. Ordinarily, the closing lag of the inlet valve should increase with rising speeds, to take into account the inertia effect of the entering air column. P. M. Heldt mentions racing gasoline engines in which the inlet valve was held open up to 90 deg. past the bottom dead center and points out that such an engine would have an excessive compression loss at low operating speeds, due to thrusting back some of the charge into the inlet passage. The only significant difference between gasoline and Diesel engines in this respect is that the opening of the inlet valve of the Diesel engine can be advanced so far that it overlaps the closing of the exhaust valve, because no danger of back-firing is present.

Whereas gasoline engines may require an inlet-opening lag up to 15 deg. past the upper dead center, Diesel engines frequently have an opening lead of about the same amount, with the result that better filling of the cylinder is provided, at least during the early part of the suction stroke. Late closing of the inlet valve is essential for good volumetric efficiency at high speeds, but the loss in effective compression ratio, as indicated in Fig. 10, is liable to be very serious from the viewpoint of operating Diesel engines at reduced speeds. Actual compression measurements, made at normal operating temperature by an Okill indicator on the four-cylinder Oberhaensli, are plotted on Fig. 21 and confirm the belief that the compression pressure of an automotive Diesel engine falls off markedly as the speed is reduced. The pressure shows a decided peak at about 1200 r.p.m. Below this speed redischarge losses probably predominate, and above it the increased wire-drawing offsets the supercharging due to inertia. Appreciable leakage of valves or piston-rings is regarded as a less likely explanation of the loss in compression at the lower speeds,

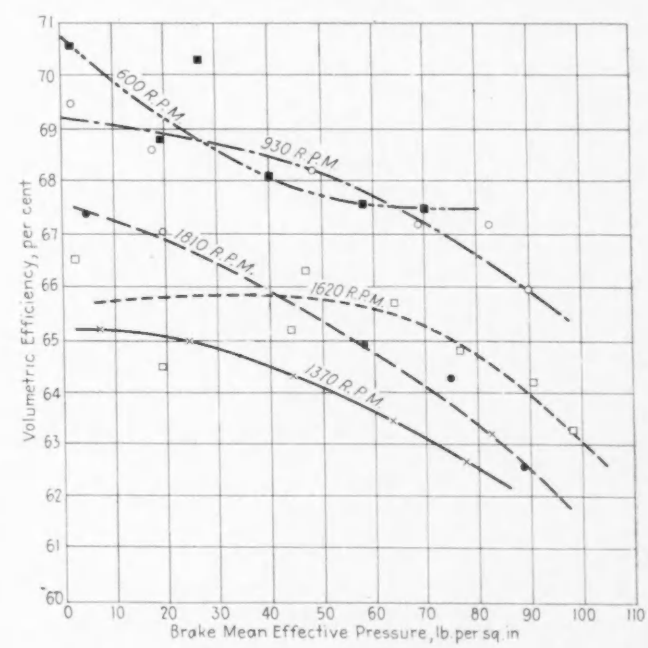


FIG. 11—RELATIONSHIP BETWEEN MEASURED VOLUMETRIC EFFICIENCY AND BRAKE MEAN EFFECTIVE PRESSURE OF THE SIX-CYLINDER OBERHAENSLI ENGINE AT VARIOUS SPEEDS

for reasons based on CO_2 measurements that will be cited later. Attention is drawn to the probability that the loss in engine capacity indicated by Fig. 21 is not in proportion to the measured values of compression, because the impairment in Diesel combustion efficiency resulting from reduction in compression enhances the purely volumetric losses.

Engine temperature affects volumetric efficiency insofar as it influences the density of the charge at the instant of beginning compression. Some indication of this is given in Fig. 11, which shows the relationship between volumetric efficiency, as measured with an orifice-type air-meter, and the brake mean effective pressure of the six-cylinder Oberhaensli engine. As a possible explanation of the fall in volumetric efficiency associated with rising brake mean effective pressure, the engine temperature might be inferred to rise and the weight of the indrawn air charge to fall off. The effective valve diameter of the Oberhaensli engines is approximately 0.4 of the cylinder bore, but reason exists for believing that, in the case of the six-cylinder machine, the relatively low volumetric efficiency of approximately 62 per cent was accounted for by the design of the inlet-valve passages and by the use of an orifice to measure the inlet air during tests.

Combustion Efficiency

Of the air that gets into the cylinder after the various volumetric losses have been deducted, less than 100 per cent is known to unite with the fuel, because oxygen

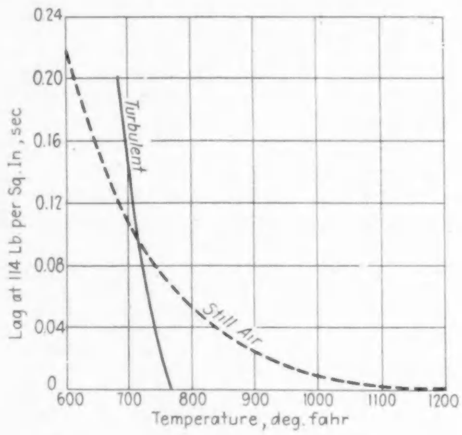


FIG. 12—EFFECT OF TURBULENCE ON IGNITION LAG

can always be detected in the exhaust gases, even when an oversupply of fuel is injected and heavy smoke is produced.

The ability of a Diesel combustion system to make full use of the available air (displacement minus volumetric losses) varies with the speed. If the performance were constant in this respect, the brake mean effective pressure would always be directly proportional to the volumetric efficiency, which is far from being true in real engines. Actually, the combustion coefficient U, which is the ratio between the quantity of air theoretically necessary to produce the work of one stroke and the displacement less volumetric losses, varies independently of the volumetric efficiency, as it is essentially dependent upon entirely different phenomena: (*a*) velocity of turbulence, (*b*) fuel-injection pressure and (*c*) compression pressure, as affected by valve timing, engine speed and leakage from the cylinder.

Attention is called especially to the fact that the combustion coefficient U, as defined in the foregoing, is *not* the reciprocal of the excess-air coefficient j which is the ratio between the air actually available and the air required for complete combustion of the fuel consumed, as calculated from the chemical composition of the fuel.

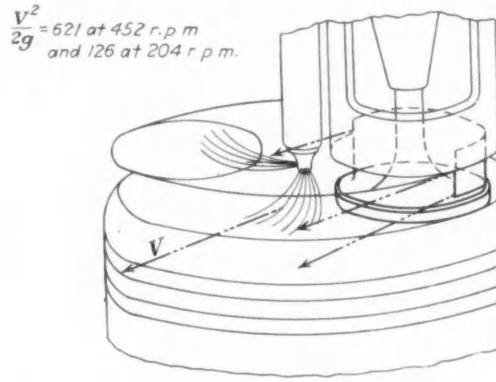


FIG. 13—DIAGRAM INDICATING TURBULENCE IN HESSELMANN-TYPE ENGINE

The excess-air coefficient gives an indication of the quantity of air that reacts chemically in the engine, but this quantity is always greater than would have been theoretically required to develop the measured mean indicated pressure or brake mean effective pressure, under the assumption that the liberated heat was applied in accordance with thermodynamic laws. Some of the fuel hydrocarbons, for instance, are not improbably consumed on their way out through the exhaust valve without adding to the power output. In that case, the measured excess-air coefficient is exactly the same as though the heat had been thrown off shortly after the dead-center position of the piston. Hence the value of the excess-air coefficient is merely as a parameter for the determination of volumetric efficiency, and a more reliable indication of the effectiveness of combustion from the viewpoint of power production must rest on a different basis. An attempt has been made to provide such a basis in the combustion coefficient, by computing how much heat would be necessary to develop an ideal diagram having a mean pressure equal to the observed mean pressure and determining how much air must be burned to liberate that quantity of heat.

Combustion Coefficient as a Function of Speed

Because of the infinitesimal time intervals available in a Diesel engine for mixture formation, the value of the combustion coefficient seems to depend more on the time lag of ignition than on anything else. The longer the lag is, the greater is the proportion of fuel burned at low efficiency during the late portions of expansion or even during the exhaust stroke. The remedy for late burning has been found principally in the provision of high turbulence, whose effectiveness for reducing ignition lag has been amply demonstrated.

Dr. Kurt Neumann is one of the authorities who experimentally demonstrated the vital importance of turbulence[4] and the curves of Fig 12 are plotted from his data. At all temperatures required for compression ignition, the time lag for turbulent air is appreciably lower than for still air. Under the conditions of Dr. Neumann's experiments, no measurable time lag of ignition is found in turbulent air above about 770 deg. fahr., whereas in still air the temperature must be increased to some 1200 deg. before the ignition lag becomes zero.

The lower the engine speed is, the greater is the ignition lag due to reduced turbulence. Turbulence is set

[4] See *Zeitschrift des Vereines Deutscher Ingenieure*, Sept. 8, 1928, p. 1241.

up in open-chamber engines accidentally or designedly and exerts a marked effect on the minimum attainable speed. The single-cylinder engine of the general type shown in Fig. 13 apparently is incapable of satisfactory ignition below 40 per cent of the maximum speed.

Turbulence in divided-chamber engines,like that shown in Fig. 9, is directly measured by the rate of speed at which air is translated from one subdivision of the chamber through a throat or passageway; as will be seen from Fig. 14, the peak of this speed is likely to be reached at about 33 deg. before dead center. Naturally, the height of this peak is a function of the engine speed and justifies the expectation that the subdivision of the chamber for purposes of turbulence is less effective at the minimum possible idling speed, about 15 per cent of the maximum speed. Assuming that the subdivided chamber always gives higher turbulence than the simple chamber is safe, even when the inlet valves or passages are very specially formed to induce rotary turbulence. Variable-speed data on high-speed automotive Diesel engines are scarce in published literature. As long as little or nothing is disclosed about low-speed turbulence, either accidental or induced, in simple-chamber engines, the divided-chamber engines may be assumed to have superior combustion over the low-speed range.

Another factor that may favor the low-speed performance of engines with divided chambers is the provision of heat-storage elements, which increase the temperature of the air beyond that which it would attain because of compression alone. Such heat-storage elements are mostly impractical in simple-chamber engines because of expansion and deficient mechanical strength.

Low-speed operation is likely to impair the atomization of the fuel by open nozzles, as the fuel-injection pressure falls with the square of the speed. Differential needles (Fig. 15) theoretically give a constant injection pressure which should be independent of the speed. Probably these also work with lower pressure when the speed is reduced, because dynamic effects such as liquid hammer are then substantially reduced, but undoubtedly nozzles having differential needles atomize noticeably better at low speeds than do injectors not equipped with a pressure-stabilizing feature.

Ample experimental evidence supports the view that loss of compression pressure impairs combustion, principally because the time lag of ignition is markedly affected by the temperature and density of the air. As has already been pointed out, the timing of the inlet valve to give good volumetric efficiency at high speeds causes redischarge losses at low speeds, so that not only air weight but also combustion efficiency are sacrificed. Combustion at low speeds will be still further impaired if valves or piston-rings are leaky.

Data are lacking on Diesel combustion efficiency, referred to air quantities actually available in the cylinder, at various speeds, and particularly at low speeds, and this lack is regarded as a serious impediment to automotive work. The effectiveness of the research that shall be done on this phase of the development will have an unmistakable bearing on commercial developments. The time seems to be past when primary emphasis will be laid on the operation of Diesel engines at high speeds; slow-speed operation of high-speed Diesel engines seems to be a much more absorbing problem of the moment.

We still have with us the paradox of the world's most advanced type of internal-combustion engine substantially excluded from application to the world's chief industry, in which such engines are needed. More thoroughness in dealing with the low-speed question may eliminate the paradox.

[5] See Dieselmaschinen V, p. 103; VDI Verlag, Berlin, 1932.

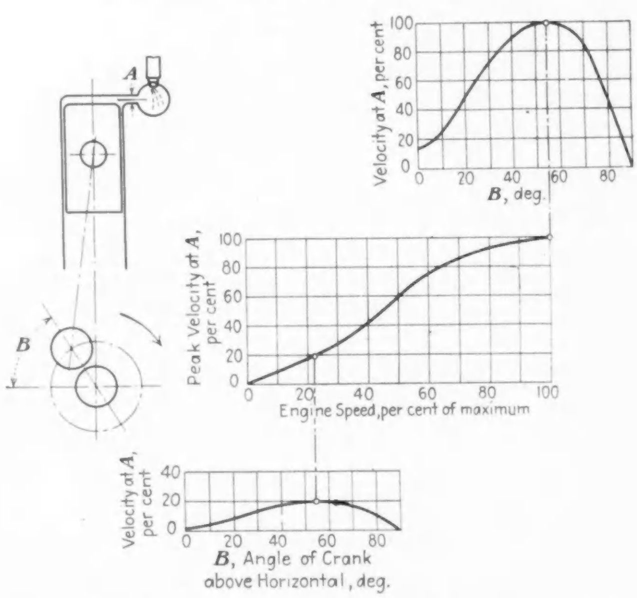


FIG. 14—VELOCITY OF TURBULENCE IN OBERHAENSLI ENGINE AT VARIOUS SPEEDS AND CRANK ANGLES

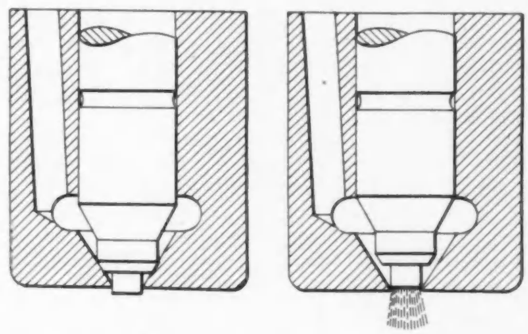


FIG. 15—DIFFERENTIAL NEEDLE TO MAKE INJECTION PRESSURE LESS DEPENDENT ON SPEED

Air Quantity as a Function of Mean Pressure

Observed brake mean effective pressure and mechanical efficiency give a clue to the quantity of air that effectively participates in combustion. Dr. A. Loschge, of the Munich Technical High School, uses this as the basis of computing the air quantities[5], but only for one engine speed. He assumes that the ratio of the displaced air to the quantity of air computed on the basis of mean pressure is the excess-air coefficient; but this seems to be an error, for reasons already given. He points with satisfaction to the agreement between his theoretically computed excess-air coefficient and the one that he determined from the percentage of CO_2 and the fuel flow; but this is regarded merely as a reflection on the accuracy of his assumptions, one of which is that the temperature of the air at the beginning of compression is 15 deg. cent. (59 deg. fahr.).

From a theoretical indicator diagram such as the one outlined in Fig. 16, Dr. Loschge calculates both excess air and mean indicated pressure as a function of the variable cut-off ratio x, which is the ratio of the volume swept during combustion plus the clearance to the clearance volume. As this factor increases, both the quantity of fuel consumed and the brake mean effective pressure developed increase with it. The ratio of the heat input of the diagram to the total heat that would have been liberated if all the displaced air had been

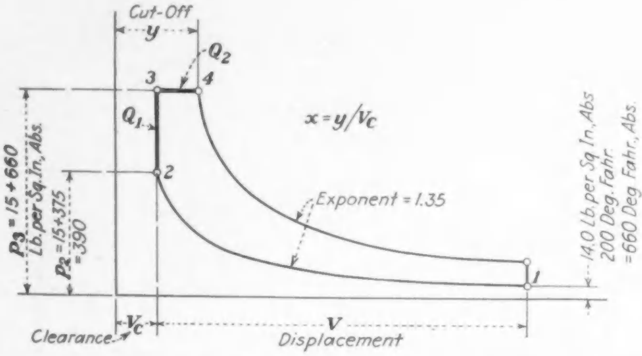


FIG. 16—THEORETICAL INDICATOR DIAGRAM OF A DIESEL ENGINE

utilized is also the ratio of used air to available air.

$$u = \frac{\text{theoretically required quantity of air}}{\text{quantity of air based on displacement}}$$
$$= \frac{\text{heat input according to diagram}}{\text{heat from burning entire quantity of air}}$$

According to Fig. 16, a portion, Q_1, of the heat is assumed to result from combustion at constant volume between the absolute compression pressure p_2 and the firing pressure p_3, while the remainder Q_2 of the heat is liberated at constant pressure between the clearance volume V_c and the cut-off volume y, the total heat input being $Q_0 = Q_1 + Q_2$. Accordingly, the heat corresponding to the energy of the diagram is

$$Q_0 = C_v\,(T_3 - T_2) + C_v k\,(T_4 - T_3)$$
$$T_2 = T_1 z^{k-1}$$
$$T_3 = T_2 w = T_1 w z^{k-1}$$
$$T_4 = T_3 x = T_1 w x z^{k-1}$$
$$Q_0 = C_v\,T_1 z^{k-1}[w - 1 + kw\,(x - 1)] \qquad (2)$$

Formula (2) gives results in terms of British thermal units per pound of air, and it is regarded as having no variable other than x, the cut-off ratio. In a cylinder of V cubic feet piston displacement, the theoretical quantity of heat necessary to cause the indicator diagram to fill out to the point x would be

$$Q_d = 0.08073\,Q_0 V \qquad (3)$$

This applies to standard conditions of 32 deg. fahr. and 29.92 in. Hg., 0.08073 lb. being the weight of 1 cu. ft. of air under those conditions.

The heat Q_f, which would be liberated if all the air in the cylinder of volume V were consumed, is arrived at by noting that 14.4 lb. of air is required for the theoretically complete combustion of every pound of fuel. If H British thermal units per pound denotes the lower heating value of the fuel, the maximum heat attainable would be

$$Q_f = 0.08073\,HV/14.4 \qquad (4)$$

Formulas (3) and (4) are not corrected for actual suction pressures and temperatures nor for effect of clearance, because the same corrections would apply to both and would cancel out in dividing Q_d by Q_f to obtain u, the efficiency of air utilization, as follows:

$$u = \frac{0.08073\,VC_vT_1z^{k-1}[w - 1 + kw\,(x - 1)]}{0.08073\,HV/14.4}$$
$$= (14.4/H)\,C_vT_1z^{k-1}\,[w - 1 + kw\,(x - 1)] \qquad (5)$$

The greater the suction temperature is the higher becomes the theoretical air factor u, because the engine is credited with producing a given mean pressure with a smaller weight of air for combustion. The suction temperature is assumed to be 200 deg. fahr., according to which $T_1 = 660$.

Formula (5) makes possible the calculation of air factors as a function of the cut-off ratio (Fig. 16); as the latter increases, the combustion efficiency also obviously increases. It is not applicable for $u > 1$.

The theoretical mean indicated pressure P also can be calculated as a function of x, the cut-off ratio, again using the theoretical indicator card of Fig. 16 as a basis. Accordingly,

$$P = \frac{p_1 z}{(z-1)\,(k-1)} \times$$
$$[xw\,(z^{k-1} - x^{k-1} + k - 1) - z^{k-1} - w\,(k-1) + 1] \qquad (6)$$

The theoretical air requirement can be determined as a function of P, the mean indicated pressure, by assuming various values of x and substituting them in Formulas (5) and (6).

Motoring tests of the four-cylinder engine, as recorded in the curve of friction brake mean effective pressure in Fig. 21, gave a tolerably good indication of its mechanical efficiency, so that the theoretical air factor u can be determined much more conveniently by a relationship that involves the brake mean effective pressure p instead of the mean indicated pressure P by assuming that the mechanical efficiency remains constant at 75 per cent, although the motoring tests naturally show some variation from this figure. This is based on

$$u = \frac{\text{theoretically necessary air}}{\text{displacement}} \qquad (7)$$

Complete filling of the cylinder is assumed in deriving Formula (6), so that the relation $u = f\,(p)$, shown in Fig. 17, merely shows what fraction of the gross displacement would be needed for the production of the stated mean pressures under theoretical assumptions such as no thermodynamic losses, constant specific heat and an initial compression temperature of 200 deg. fahr. Naturally, the validity of a theoretical indicator card based on such assumptions might be questioned, just as authorities on thermodynamics have thus far failed to agree on an ideal air-cycle diagram against which to measure experimentally determined thermal efficiencies. However, examining questions of this kind is not within the province of the present paper; rather, my purpose has been to establish a workable standard of comparison, as errors in comparison are eliminated if the theoretical air factor is arrived at with the same assumptions for all cases.

Errors result, of course, from the assumptions that the compression pressure, firing ratio and initial compression temperature are the same for all speeds, but an effort to allow for variations of this kind would needlessly complicate the procedure, with no gain in accuracy of comparisons. Such a gain can be realized only when better facilities for indicating become commercially available. The Industrial Instrument Co.'s electrical point-by-point indicator is free from lag and inertia and is admirably suited to yield better experimental ground-work for computations like those undertaken in this paper.

Accepting the validity of the function u makes possible ascertaining the theoretical air requirement by merely multiplying by the piston displacement. The number of cubic feet per hour arrived at in this manner is less than the number of cubic feet obtained by direct measurement through an orifice, from CO_2 analysis or from displacement, and the difference should be an indication of the air inherently wasted in combustion. Using the ratio instead of the difference to determine the combustion coefficient,

$$U = \frac{\text{theoretically necessary air}}{\text{air actually available}}$$

Since the volumetric efficiency is

$$e = \frac{\text{air actually available}}{\text{displacement}}$$

and the net air coefficient can be written

$$E = \frac{\text{theoretically necessary air}}{\text{displacement}}$$

then

$$E = Ue \qquad (8)$$

Formula (8) indicates that the specific air capacity of an engine can be represented as the product of two factors of coordinate importance; namely, the volumetric efficiency and the combustion coefficient. In nearly all practical engines, both of these quantities are appreciably affected by variations in engine speed, and the volumetric efficiency may be said in general to fall and the combustion coefficient to rise, up to a point where the product of the two is the maximum and the torque of the engine is at its peak. The variation of the factors over the entire speed range is of obvious importance for automotive service, and Diesel-engine data for one speed only are virtually useless.

Air Tests on Engines

The air actually entering an engine under test can be measured in the following three ways, which are named in the descending order of their accuracy and in the ascending order of their convenience:

(1) Displacement meter
(2) Calibrated orifice
(3) Exhaust-gas analysis

These methods were used respectively for the tests on the single-cylinder, six-cylinder and four-cylinder engines that are reported in this paper. Important dimensions of these engines are listed in Table 2.

Fritz Schmidt, who reported[6] the test on the single-cylinder 8.27 × 11.8-in. Hesselmann engine, used a displacement meter. He made simultaneous exhaust-gas analyses which seem to have been very accurate and to have closely confirmed the air-meter tests. However, he had to keep a set of rubber equalizing bags inflated to about the pressure of a 0.6-in. water-column to make the meter function. As the bags were placed between the meter and the engine, the engine actually was supercharged and showed excessively high volumetric efficiency, apparently at variance with the real operating conditions.

[6] See *Zeitschrift des Vereines Deutscher Ingenieure*, Aug. 16, 1930, p. 1151.
[7] See *The Engineer*, Oct. 16, 1931, p. 414.

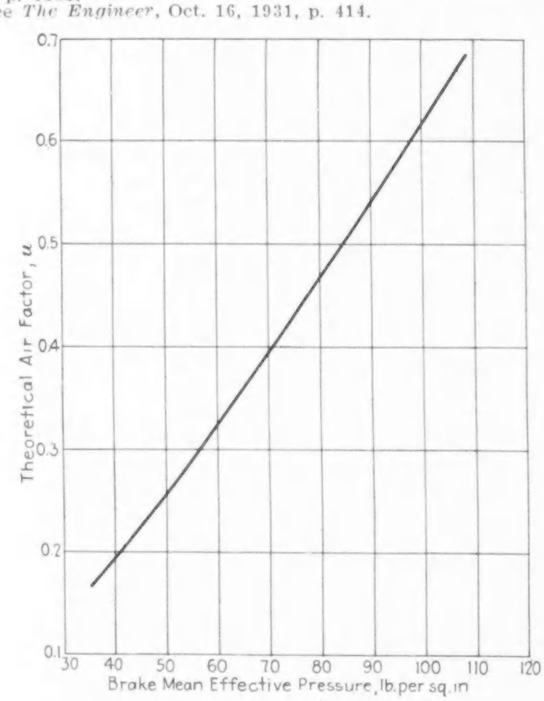


FIG. 17—THEORETICAL AIR FACTOR

Showing What Fraction of the Gross Displacement Would Be Needed To Produce a Given Mean Effective Pressure under Theoretical Conditions

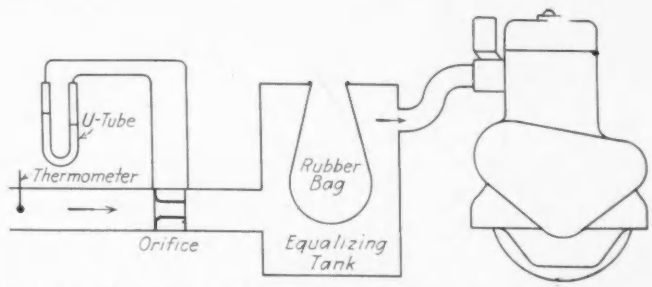


FIG. 18—SET-UP FOR MEASURING INLET AIR THROUGH AN ORIFICE

Dr. Davies measured the air for the six-cylinder Oberhaensli engine by a calibrated orifice, as shown diagrammatically in Fig. 18. As he used no blower, the low volumetric efficiencies that he reported[7] can be accounted for by loss of head due to the flow of air through the orifice.

TABLE 2—DIMENSIONS OF ENGINES TESTED

Cylinders, No.	1	6	4
Bore, in.	8.27	4.331	5.118
Stroke, in.	11.8	6.299	7.087
Displacement, cu. in.	635	553	583
Rated Brake Horsepower	22	120	110
Rated Speed, r.p.m.	350	1,800	1,800
Compression Ratio	11	13.8	13.8

Mr. Young determined the CO_2 content of the exhaust gases of the four-cylinder Oberhaensli engine, and this was used, along with the fuel flow, to determine the air flow, according to computations following a method kindly suggested to the author by Dr. Kurt Neumann. This makes possible calculating the excess-air coefficient j from a relationship involving the fraction D of CO_2 gas which is present in the exhaust gases prior to condensation of the superheated water vapor in the Orsat apparatus, as follows:

$$D = \frac{cM/12}{cM/12 + hM/2 + (j - 0.21)\,a} \qquad (9)$$

Formula (9) can be solved for j, and the term $hM/2$ can be made equal to zero to allow for the condensation of the water vapor in the Orsat apparatus. It is thus possible to find the value of j in terms of d, the observed fraction of CO_2, as

$$j = 0.21 + (cM/12\ a)\,[(1 - d)/d] \qquad (10)$$

It remains now to determine the volume of air required for complete combustion

$$a = (c/12 + h/4)\ (358.7/0.21) \qquad (11)$$

which involves the carbon and hydrogen fractions in the fuel. These are assumed to be 0.85 and 0.15 respectively, the oxygen and sulphur constituents being neglected, and the nitrogen fraction of the air being assumed as 0.79 by volume.

Efforts to obtain an approximate analysis of the fuel used in the tests of the four-cylinder engine were unsuccessful. It was a clear distillate with the following characteristics:

A.P.I. Gravity	36.1
Viscosity, Saybolt Universal at 100 Deg. Fahr., sec.	50
Flash Point, Closed Cup, deg. fahr.	195
Pour Point, deg. fahr.	30
Sulphur, per cent	0.05
Distillation Points, deg. fahr.	
Initial	324
5 Per Cent	544
Final	750

The 85:15 ratio of carbon to hydrogen is assumed to apply fairly well to this fuel, and the use of these fractions in Formula (11) gives $a = 185.0$ cu. ft. of air at standard conditions as the minimum required to burn 1 lb. of the 85:15 fuel. Variations in these proportions have a comparatively small effect on the value of a, which would change only to 179.8 if the carbon-hydrogen ratio were changed to 86:14. A one-point variation in the carbon fraction therefore causes a 1-per-cent change of excess-air coefficient from 1.447 to 1.460, a deviation that can be considered as negligible in comparison with the other errors incidental to air computations based on CO_2 content. Accordingly, the excess-air coefficient is

$$j = 0.1374\ [(1 - d)/d] + 0.21 \qquad (12)$$

where d is the fraction of CO_2 gas as observed on the dry sample by the Orsat apparatus. Hence, for every pound of fuel passing through the engine per hour, $185j$ cu. ft. of air at standard conditions must be supplied. If a pressure of 14.7 lb. per sq. in. abs. and a temperature of $80 + 460 = 540$ deg. fahr. abs. are assumed as applying to the test number of cubic feet of air handled per hour,

$$A = 203\ jF \qquad (13)$$

This formula can be applied directly to the fuel flow and CO_2 percentages given in Fig. 17 to determine how much air actually got into the engine. How much air took part in combustion can be determined from Formula (7) and Fig. 17, and the difference is the excess air shown in heavy shading on Fig. 21.

The general arrangement of the open combustion space of the single-cylinder engine tested is shown in Fig. 13, which also indicates air capacities inferred from Schmidt's volumetric data and values for mean indicated pressure. The latter were available and could be used in this instance, rather than brake mean effective pressure, so that a function u other than the one shown in Fig. 17 was used for calculating air quantities from mean pressure. For this purpose the compression ratio of 11 and a firing ratio of 1.4 were taken into account. The corresponding values for the Oberhaensli engines are 13.8 and 1.73. Insofar as indicator measurements on a 350-r.p.m. engine are questionable, the mean-indicated-pressure basis is less satisfactory, but it has the advantage of eliminating the uncertainties of mechanical-efficiency figures.

Both of the Oberhaensli engines have approximately spherical combustion chambers which communicate with the cylinder through a streamlined throat, as shown in Fig. 9, the air current entering the spherical space tangentially and rotating its contents. The location of the fuel spray is such as to subject the oil charge to the most energetic possible air movement.

Turbulence of the charge reissuing from the chamber during the early portion of the expansion stroke of the piston is enhanced by the projecting lip of the hollow shell with which the chamber is lined. Because of the slight air gap between the shell and the chamber proper, the shell ordinarily reaches a temperature of 722 deg. fahr. when the brake mean effective pressure is 91 lb. per sq. in., according to a report[8] on this type of engine by Dr. Kurt Neumann, who measured the shell temperature directly by thermocouples. He estimates that the shell is responsible for an increase in the compression temperature of the air amounting to about 180 deg., the attainment of which would require an increase of about 45 per cent in the compression pressure if the shell were not used.

No mechanical stresses are imposed on the shell, because of the free access of gases to both the interior and the exterior. As a considerable portion of the outside surface of the shell also responds to the temperature of the combustion gases and as the mass of the shell is small, it probably also adapts itself readily to rapidly varying conditions of load and speed, such as are met with in automotive service. The driving characteristics of vehicles propelled with Oberhaensli engines seem to reflect this characteristic, further evidence of which may be found in the engine's ability to run idle at approximately 15 per cent of its full speed.

Believing that the high temperature of the air compressed in the hot shell noticeably shortens the ignition lag of the fuel, to such an extent in fact that the fuel is ignited before actual impingement occurs, is reasonable. Evidence to support this view is found in the fact that satisfactory running of the engine is impossible when the fuel spray is adjusted so that markings of fuel deposition are left on the shell. When the adjustment is normal, no fuel markings can be found.

The spray valve is of the Bosch pintle type, as shown in Fig. 15, with the usual differential shoulder set for opening pressures between 2000 and 3000 lb. per sq. in. Fairly good operation is possible with the differential needles set to open at 500 lb. per sq. in., and the principal object in setting them to a definite figure is to facilitate distribution of uniform quantities of fuel to the individual cylinders.

In view of the moderate injection pressure and the use of the relatively coarse pintle spray, which has a cone angle of 45 deg., exceedingly fine atomization apparently is not sought. Turbulence induced by the streamlined tangential passage and the superheating effect of the shell are considered to be more important.

Maximum Torque and Smoke

Rotative speed was regarded as the independent variable in the tests on the Oberhaensli engines, as is customary in automotive work. For gasoline engines the common practice is to hold definite values of the speed and then to determine, by progressive increases in throttle opening and dynamometer loading, the maximum brake mean effective pressure that can be carried at the given speed. At the highest values of brake mean effective pressure, farther opening of the throttle produces no increase in torque.

This procedure apparently was not adopted in the case of the single-cylinder Diesel engine, judging by the relatively low values of brake mean effective pressure obtained, but the report of these tests does not state what standard was used in setting the torque for each of the speeds.

Dr. Davies states that the values of brake mean effective pressure were set in the test of the six-cylinder engine in accordance with the smoking margin; in other words, the throttle was opened until smoke could be observed but not beyond the point where the exhaust was satisfactory. About this he comments:

> The question of what constitutes a satisfactory exhaust is admittedly an indefinite one, and provision of some standard of comparison would be a boon, but in the present tests the author has always erred on the exacting side.

A better solution of the problem apparently was obtained by Mr. Young in testing the four-cylinder engine. Instead of the Junkers hydraulic brake used on the six-cylinder machine, he employed an electric dynamometer, which permitted of approaching the maximum-torque point with great precision. While a constant speed was maintained, throttle positions and excitation were adjusted until the maximum torque occurred, and this was observed, in each case, with what might be called moderate smoking. Apparently the electric dynamometer makes possible ascertaining maximum torque without arbitrarily exceeding the cor-

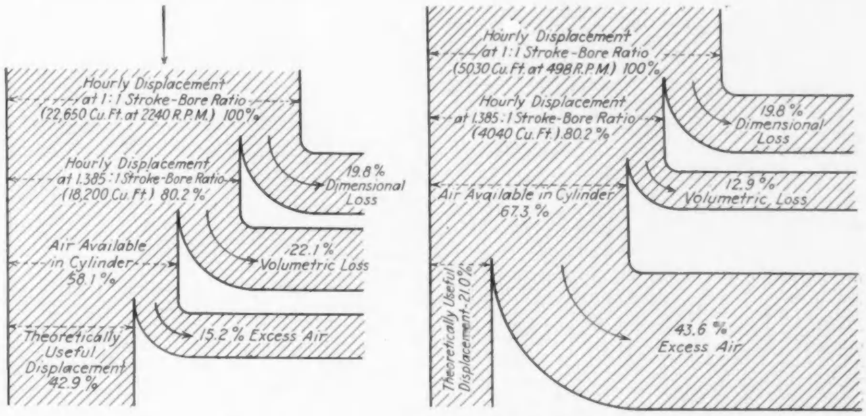
[8] See Dieselmaschinen V, p. 111; VDI Verlag, Berlin, 1932.

responding throttle position, so that the production of smoke is minimized. The tester of a Diesel engine cannot always be sure, with frictional or hydraulic dynamometers, of having reached maximum torque unless he opens the throttle wide enough to cause black smoke at the exhaust.

In appraising the test results of the single-cylinder engine, as presented in Fig. 19, the fact should be borne in mind that Mr. Schmidt probably had some standard, the nature of which he does not reveal, by which to judge the maximum brake mean effective pressure that the engine could satisfactorily develop at each speed. The high volumetric efficiency due to a certain amount of supercharging has already been commented on, but the excess air is correspondingly large. The sharp drop in brake mean effective pressure between 248 and 204 r.p.m. suggests that the combustion capacity of the engine falls off rapidly at diminishing speeds, probably because of the reduced turbulence resulting from a reduction of the air speed from 200 to 90 ft. per min. Undoubtedly this engine could be readily altered to improve its low-speed performance and to make its characteristics correspondingly more suitable for automotive purposes. Considering the fact that it is essentially a stationary engine, it approximates automotive performance to a noteworthy degree.

The tests on the six-cylinder engine, charted in Fig. 20, were carried out, as already stated, before the machine had been fully developed for commercial purposes, but they cover a considerably higher range of speeds than do the tests of the single-cylinder unit. The effects of poor volumetric efficiency become especially noticeable between 1400 and 1800 r.p.m., but they are offset by an unusually high combustion coefficient, which exceeds 85 per cent at 1700 r.p.m. Consequently, the net-air coefficient, which shows to what extent the gross displacement has been utilized, is high over this speed range. However, the amount of smoking associated with an 85-per-cent combustion coefficient might not be acceptable under American traffic conditions. Later improvements in the engine have served to decrease this coefficient, not by lowering the engine's output, but by improving its air supply. Dr. Davies is now repeating his volumetric experiments, and his new test data should afford an interesting comparison with the old data.

The low-speed performance of the incompletely developed six-cylinder engine is deficient because speeds lower than 600 r.p.m. apparently could not be attained satisfactorily. This manifests itself in a low value of the combustion coefficient at low speeds; it was only 27.5 per cent at 600 r.p.m.



CAPACITY-BALANCE DIAGRAMS FOR OBERHAENSLI 583-CU. IN. FOUR-CYLINDER ENGINE

Speeds of a 5.7 x 5.7-In. Engine To Give the Same Air Speeds through the Valves Are Assumed as a 100-Per-Cent Basis

Fig. 22—At 1800 R.P.M. Fig. 23—At 400 R.P.M.

Diesel-engine performance acceptable for automotive service is reflected in the test results of the four-cylinder engine, charted in Fig. 21, comments on which may be summarized by noting that the excess-air quantity shows consistent values over the entire speed range. The maximum combustion coefficient, which is about 78 per cent at 1500 r.p.m., is lower than the maximum obtained for the six-cylinder machine; but this is offset by better volumetric efficiency, so that the over-all air utilization is about the same. Moreover, the lower maximum combustion coefficient gives better assurance of clean burning. The minimum value of the combustion coefficient, which is 36.5 per cent at only 400 r.p.m., is also significant in the automotive performance of this particular engine.

Fig. 22 is a capacity-balance diagram for the four-cylinder engine at 1800 r.p.m., in which the dimensional loss corresponding to a stroke-bore ratio of 1.385 also is included. Some difference of opinion may exist as to the justification for including this consideration, in view of the fact that gasoline engines with unity stroke-bore ratio also are not beyond criticism. However, if Diesel engines are to be compared among themselves,

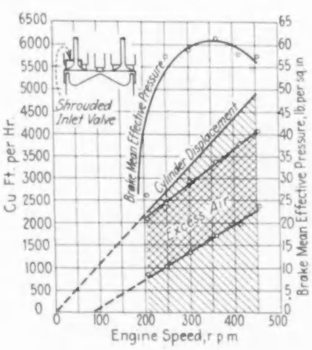


FIG. 19—RESULTS OF TESTS ON HESSELMANN SINGLE-CYLINDER, 8.27X 11.8-IN. ENGINE

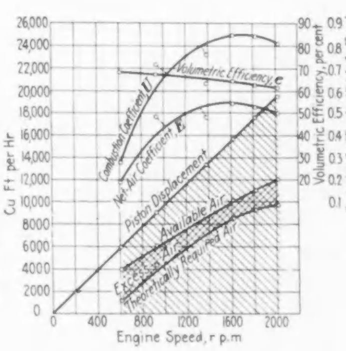


FIG. 20—RESULTS OF TESTS ON OBERHAENSLI SIX-CYLINDER 4.33X6.30-IN. ENGINE

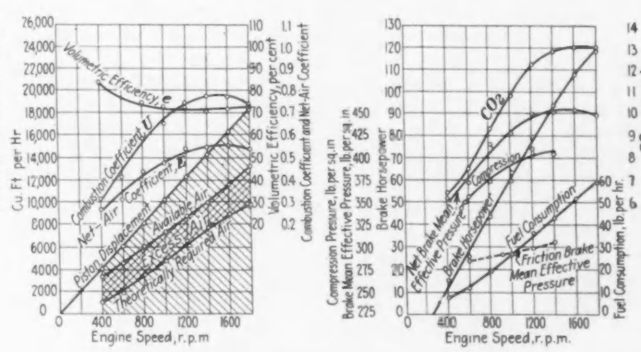


FIG. 21—RESULTS OF TESTS ON OBERHAENSLI FOUR-CYLINDER 5.118X7.087-IN. ENGINE

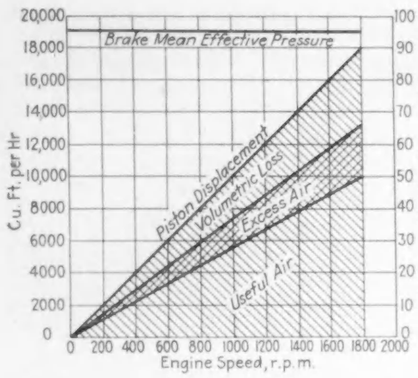


FIG. 24—AIR UTILIZATION FOR IDEAL DIESEL ENGINE

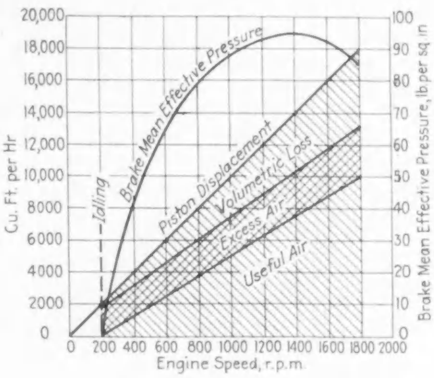


FIG. 25—AIR UTILIZATION IN PRACTICAL AUTOMOTIVE DIESEL ENGINE

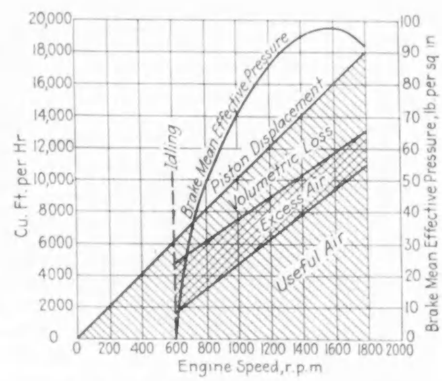


FIG. 26—AIR UTILIZATION IN A DIESEL ENGINE SUITABLE FOR MOTORBOAT PROPULSION

neglecting this ratio, which, as has already been pointed out, is rigidly determined for some of them and causes the dimensional loss in capacity shown in the diagrams, would be misleading.

Fig. 23 is another capacity-balance diagram for the four-cylinder engine, at 400 r.p.m. The volumetric loss, as might be expected, is only about one-half as great as at 1800 r.p.m., while the excess air that fails to participate in combustion is more than three times as much. Nevertheless, the ability of an 1800-r.p.m. Diesel engine to pull any load at all at 400 r.p.m. is considered noteworthy. The machine idles under governor control at 200 r.p.m. and can be held at 160 r.p.m. with manual assistance to the governor. The reductions in speed are accomplished solely by varying the delivery of the Bosch fuel-pump; no supplementary operations, such as cutting out cylinders or externally heating a part of the combustion space, are necessary.

What might be called an ideal engine, for which the performance is indicated in Fig. 24, would always operate at constant volumetric efficiency, from zero to the maximum speed and, so far as this particular factor is concerned, no unusual difficulty is experienced in obtaining a substantially constant value for it in actual engines. To indicate what an ideal Diesel engine might be like, the combustion coefficient U, showing the ratio of theoretically necessary air to air actually available, is further assumed to be a constant. This is the assumption on which Fig. 24 is based, and from it follows as a logical consequence that the line showing theoretically necessary air should pass through zero, while a constant value of brake mean effective pressure is maintained over the entire operating range. This condition, of course, is realized only in the steam engine; no known internal-combustion engine will develop any measurable power as the speed approaches zero.

Characteristics of what might be an actual Diesel engine having satisfactory automotive characteristics are illustrated in Fig. 25. Its outstanding characteristic is the ability to make good use of the available air at low speeds, which is important, not only for idling, but also for rapidly building up torque as required for acceleration from low speed. By contrast, Fig. 26 represents an engine deficient in combustion at low speeds but possessing an excellent high-speed characteristic. An ideal application for such an engine would be motorboat propulsion, as the propeller torque automatically reduces itself far below the possible engine torque when the speed is reduced.

Much has been written about the ability of Diesel combustion systems to function at high speed, but my observations indicate that the problem of low-speed combustion is considerably more acute. In any event automotive Diesel combustion should always be considered as a function of the entire speed range, for which purpose a knowledge of air characteristics seems to be of primary importance. The determination of air characteristics by test is fairly easy, and they afford a comprehensive basis for appraisal.

THE DISCUSSION

EDWARD T. VINCENT[9]:—Mr. Kuttner's paper is full of valuable material which has been presented in an interesting manner. The air charge of Diesel engines unquestionably is of fundamental importance, and every effort should be made to increase the weight of air in the cylinder. This point is well stressed in the paper; however, not sufficient emphasis is given to combustion efficiency, which is mentioned and dealt with in some detail but its real importance is not brought out. What is the use of having even 100-per-cent volumetric efficiency if the injection apparatus is capable of dealing with only 50 per cent of the air in the cylinder? These two factors must go hand in hand, and injection characteristics should be modified until the engine is capable of using a high percentage of the air contained in the cylinder at all speeds rather than 85 per cent at maximum torque and only 40 per cent at low speeds.

The comparison of various stroke-bore ratios shown in Fig. 1 is of interest; but does it represent what we are really concerned with? The speed changes from 500 to 1000 r.p.m., and such variation is not permissible for an engine required for a particular duty; for automotive purposes, an engine of say 2000 r.p.m. is desirable, and one of 1000 r.p.m. has little chance of success. A better comparison would have been made and possibly different conclusions reached if various stroke-bore ratios had been assumed for a constant speed of rotation and horsepower.

That stroke-bore ratios of 1:1 to 1.25:1 are not so difficult to handle is shown by the following figures:

Bore, in.	20	14½	6¾
Stroke, in.	20	15	7½
Ratio	1	1.035	1.11
Brake Horsepower	398	100	115
Engine Speed, r.p.m.	400	380	1,000
Brake Mean Effective Pressure, lb. per sq. in.	125	84	85
Fuel Consumption, lb. per b.hp-hr.	0.426	0.41	0.41

These figures cover a sufficiently wide range of engine sizes and speeds to indicate that stroke-bore ratio

[9] Diesel research engineer, Continental Motors Corp., Detroit.

is of little consequence, and a complete change of laws will hardly result from changing the bore and stroke from those in the last column to those of the four-cylinder Oberhaensli engine.

Turning to the question of volumetric efficiency, the Diesel engine is certainly at some advantage, as compared with gasoline engines, because of the absence of the restriction of the carbureter. Against this must be set the absence of vaporization of the fuel during suction; which, a careful analysis will show, generally results in a greater volumetric efficiency for the gasoline engine. Another fact which demonstrates this is that, for similar gasoline and Diesel engines running at the same speed, maximum efficiency necessitates closing the inlet of the Diesel considerably earlier than that of the gasoline engine, 25 deg. earlier at 1400 r.p.m. and 20 deg. at 800 r.p.m. The values given in Fig. 21 for the drop in compression with speed are of little value, since obtaining reliable results with an Okill indicator at speeds above about 600 r.p.m. is impossible. However, the general trend of the curve probably is indicated with sufficient accuracy for the point the author wishes to make.

Combustion efficiency is far more important than volumetric efficiency. Mr. Kuttner's treatment of this side of the problem is of very considerable interest, but the wide variations possible between the various types of injection system is not brought out. Analysis of the results already given for open-chamber engines will show that this type of engine is superior as regards combustion efficiency to the divided-chamber engine, even at slow speed. Whether or not the engine has slow-speed turbulence does not seem to matter, since the open-chamber engine is capable of carrying more load with a clean exhaust at slow speed than is the other. Since the single-chamber also starts very easily with lower compression-ratios than does the divided, and without heating elements, the heat-storage feature of the latter type does not seem to be of great consequence.

I join with the author in a request for some standard of reference as regards smoke. This factor varies so much with different individuals and with the same person on various days or even on the same day, according to the background, that an accurate estimate is impossible. At present only one real criterion is worth while; that is, an absolutely invisible exhaust under any circumstances. If this standard were applied to all engines, the ratings of many would be cut considerably.

Mr. Kuttner considers it noteworthy that an 1800-r.p.m. Diesel should pull any load at 400 r.p.m., a speed range of 4.5:1, but open-chamber engines show that speed ranges of about 10:1 are possible, as I have mentioned. A Beardmore airplane-type engine weighing 3.3 lb. per b.hp. at 1400 r.p.m. would idle at 400 r.p.m. when directly connected to a dynamometer with no flywheel or propeller. With a flywheel equal in inertia to the propeller, speeds as low as 200 r.p.m. were possible; a speed range of 7:1. In addition, constant-torque characteristics were obtained down to the slowest speed.

The author has presented certain aspects of oil-engine operation in a very interesting way, his methods of calculating the various coefficients are worthy of much study and many other points are well taken.

Aids to Volumetric Efficiency

CHARLES O. GUERNSEY[10]:—Mr. Kuttner is to be congratulated for putting emphasis on one phase of Diesel-engine design which, while apparently obvious, has nevertheless seemingly been overlooked by many Diesel-engine designers, particularly those working on automotive types. That internal-combustion engines, whether of the Diesel or the Otto cycle, will have performances substantially proportionate to their efficiencies as air-pumps, other things being equal, seems axiomatic.

Many designers seem to have been so concerned with combustion-chamber design and combustion phenomena that they have neglected this fact. Sometimes, indeed, the volumetric efficiency or breathing capacity of the engine seemingly has been deliberately restricted as a means of bringing about other desired results. Sometimes the valve size is limited because of the very long stroke-bore ratio; sometimes it is limited by the location of the fuel nozzle; in other cases the capacity of the valves has been restricted by shrouding or restricted or distorted intake passages—all justifiable, perhaps, in the light of other considerations, but nevertheless reacting very heavily against the ultimate success of the design by reason of impaired volumetric efficiency.

Open Chamber Can Give Flexibility

With some of Mr. Kuttner's conclusions I cannot agree. He seems to dismiss the open-combustion-chamber engine as having limitations that prevent its satisfactory use over a wide range of speed and load. Perhaps flexibility is much easier to get in an engine having a divided combustion-chamber. However, results have been obtained with open-combustion-chamber engines which indicate that the power output over a very wide range of speeds is limited only by the quantity of air that is available to support combustion; indeed, that the speed limitations are largely mechanical and that no reason is apparent why open-chamber Diesel engines cannot be designed to give mean effective pressures and speed ranges equal or superior to those of the Otto-cycle engine.

The divided combustion-chamber seems to have numerous disadvantages. Its use admittedly makes the problem of proper combustion much easier, but at the expense of lowered volumetric efficiency, higher fuel consumption, lower mean effective pressures and, in some cases, rough combustion. It seems to be at least substantially true that the more complicated the combustion chamber is, by things like divisions, shells and chambers, the greater will be the heat loss, and consequently the less will be the power and the higher the fuel consumption. It seems reasonable to expect the fuel consumption to increase or the power to decrease, or a combination of the two, substantially in proportion to the increased heat loss brought about by such divided chambers.

Mr. Kuttner speaks of combustion lag and slow burning as being detrimental to the open-chamber engine. A distinction should be made between the initial ignition lag, which can be dealt with by suitable injection timing, and combustion lag after ignition has started. Experiments have shown that, with good design, the combustion lag need not be detrimental in an open-chamber engine.

In one other particular I believe that Mr. Kuttner has arrived at a conclusion which should be further investigated. He dismisses engines having low stroke-bore ratios with the comment that such ratios may be responsible for some of the shortcomings of engines so arranged. Tests with an engine having a stroke-bore ratio of 1.24 have shown entirely satisfactory results in every respect; in fact, an open-chamber engine gives results which, when plotted on Mr. Kuttner's Fig. 25, show mean effective pressures far exceeding those indicated by Mr. Kuttner as representing good practice.

One further point may be of interest. In judging the exhaust from a Diesel engine, the practice hereto-

[10] M.S.A.E.—Chief automotive engineer, J. G. Brill Co., Philadelphia.

fore with most experimenters has been to class the exhaust as good, fair, poor or bad or as black, brown or grey. In certain Diesel-engine tests that have been made, definite standards were set up for judging the nature of the exhaust. The Ringleman charts, which are recognized as the means of judging smoke on steam powerplants, are graded as Nos. 1, 2, 3 and so forth, but even No. 1 is far too dark for a satisfactory Diesel exhaust. Therefore, additional charts like those shown in Fig. 27 were made up and numbered 0, 00 and 000, and these were used for judging the exhaust. During the tests mentioned, any exhaust darker than No. 000 was considered unsatisfactory. All of the results to which I have referred were achieved with an exhaust at least equal to the No. 000 chart.

Diesel Cycle Approximates Air Cycle

ROBERTSON MATTHEWS[11]:—All internal-combustion engines are in reality air-engines in which the fuel is simply an activator of the air, and oil-engine analysis has been approached too little from the air side. The author does well to stress the acuteness of the combustion problem in compression-ignited engines for the automotive field during operation at low speed. The compression-ignited engine is a purer form of heat engine than is the spark-ignited, and its behavior rests on a different basis.

Concerning air pockets in combustion chambers of engines into which the fuel is injected, the extent to which pockets can diminish air utilization is difficult to estimate because of the cross-play of influences. The Junkers and Ricardo designs seem to have the most symmetrical combustion-chamber forms yet developed, and they lead in excellence of fuel utilization. But if the brake mean effective pressure attained is taken as the measure of *air* utilization, these designs seem to have been surpassed by some others with less symmetrical combustion chambers. However, if attainment of smooth running had not been a deciding factor, perhaps the comparison would be still different.

Should small dimples in the surface of combustion chambers with internal injection be found to be highly detrimental to air utilization, this would seem to indicate that the movement of fuel particles resulting from combustion is small. Is there no such thing as combustion turbulence? A combustion chamber containing a streaky mixture and having boundaries of unequal temperature apparently would favor localization rather than the spread of combustion. This would give momentary local pressure changes which would at least set up pressure waves in a symmetrical chamber. But what would occur in an unsymmetrical chamber? Eddy currents? If so, such currents would be combustion turbulence, which possibly should be considered in combustion-chamber design, although wholly incapable of taking the place of directed or controlled turbulence, as those terms are now understood.

If the surface layer of air of a combustion chamber is considered to be of doubtful availability, increase of surface area by pockets may deserve attention, as well as the isolation of the air.

Stresses Utilization of Air

Having had some experience with attempts to put across a term that should aid oil-engine development by stressing data on *air* utilization, I am inclined to question whether the author's presentation of combustion efficiency and what follows it is not a little too involved; its simplification is worthy of more labor.

For a long time I have believed, though admitting the tediousness introduced, that makers of economical engines would find having their test data include a term showing the ratio of the air utilized to the air supplied by the engine, a sort of air-capacity ratio, advantageous. Such a term should have more direct significance than the customary excess-air coefficient and air-fuel ratio, which, taken directly, are broadly indications of the volume of air needed to coax combustion rather than

[11] M.S.A.E.—Research and development engineer, Bolton, Ont., Canada.

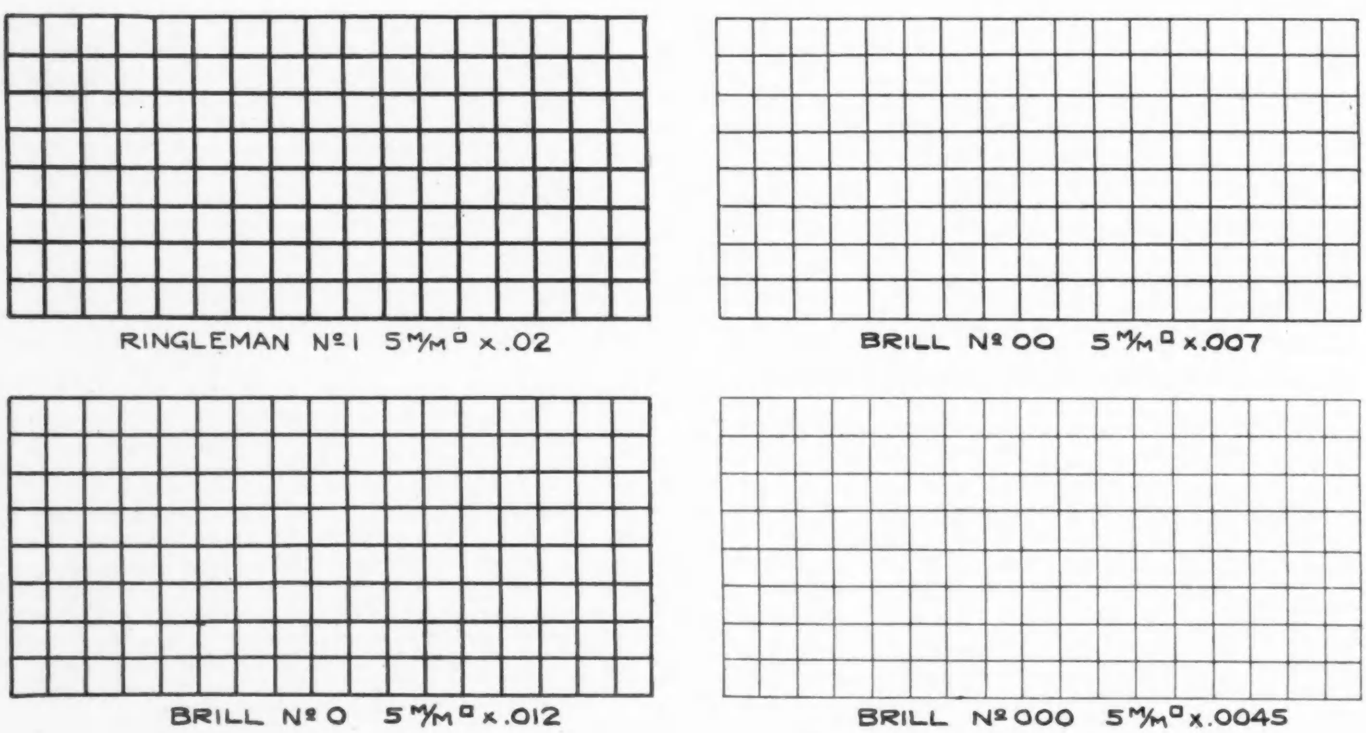


FIG. 27—SCALE CHARTS FOR MEASURING SMOKINESS OF EXHAUST

specific determinations of the proportion of air that is utilized at given loads and consequently at different fuel economies.

H. D. HILL[12]:—Divided-chamber engines seem to be in the ascendancy among Diesel engines of small sizes. However, the precombustion-chamber engine has the serious defect that the pressure difference between the antechamber and the cylinder is much greater at low speeds and light loads than at high speeds and heavy loads. This is exactly opposite to the condition that should prevail, because, when a small quantity of fuel is being burned, great turbulence is not necessary. Promotion of turbulence is one of the chief advantages of the antechamber. When the load is heavy and the quantity of fuel is large, the pressure in the antechamber is lowest and consequently the turbulence is least.

In our development work we have succeeded in correcting this condition to a considerable extent by introducing a second spray valve discharging directly into the cylinder. The first valve discharges a constant quantity of fuel into the antechamber, thus maintaining a constant pressure in the antechamber throughout the entire load range. The additional fuel required by the heavier load is introduced into the cylinder in the path of the gas issuing from the antechamber. In that way the main body of fuel is subjected to higher temperature, and the turbulence needed to mix the fuel thoroughly with the air is obtained.

Applying the Principles of the Paper

A. C. STALEY[13]:—Mr. Kuttner's paper represents a conscientious effort to analyze the possibilities of the automotive Diesel engine. Only by such concentrated and continuous attack on its many problems will the wilderness of the unknown become the cultivated field of the known. The method of attack is somewhat novel and provocative. The attempt to evaluate pocketing and so-called dimensional losses is instructive.

A little further clarification as to the author's use of Equation (1) would be appreciated. He says, "Very large capacities could be obtained by merely reducing the value of r." If this is done by reducing the stroke, V will be reduced, and consequently the power, unless n is increased in like ratio. The value of r can be decreased by holding the stroke constant and increasing the bore; but this is merely equivalent to saying that increasing the bore increases the capacity, which is more or less obvious.

I should also like to obtain additional information on the author's treatment of dead pockets. While the arrangement of the combustion chamber and clearance space bears an important relation to the combustion of the fuel in the cylinder, combustion in a true Diesel engine continues during a portion of the piston travel, particularly at heavy loads. Is not the air in the so-called dead pockets released for use during the later period of combustion? At part load, not all of the air is needed to burn the fuel completely, and the pockets should not be troublesome during such operation.

The term combustion coefficient, represented by U, is stated to be the ratio of the theoretical to the supplied air, if my interpretation of displacement-volumetric losses is correct. If such is the case, U becomes the reciprocal of the excess-air coefficient, the latter being the ratio of air used to that required. Why does not the combustion coefficient also take into account incomplete combustion, which as we all know is a particularly serious problem? The combustion coefficient might then represent the ratio of the air utilized to that furnished. Determination of the degree of utilization presupposes a satisfactory method of exhaust-gas analysis, including both products of combustion and the detection of unburned fuel in addition to the usual procedure.

In view of the fact that the Diesel engine should be, both thermodynamically and actually, the most efficient of any present prime mover, the fact that its mean effective pressure is generally lower than that of the Otto-cycle engine reflects unpleasantly upon our ability as combustion engineers. We should do something about it.

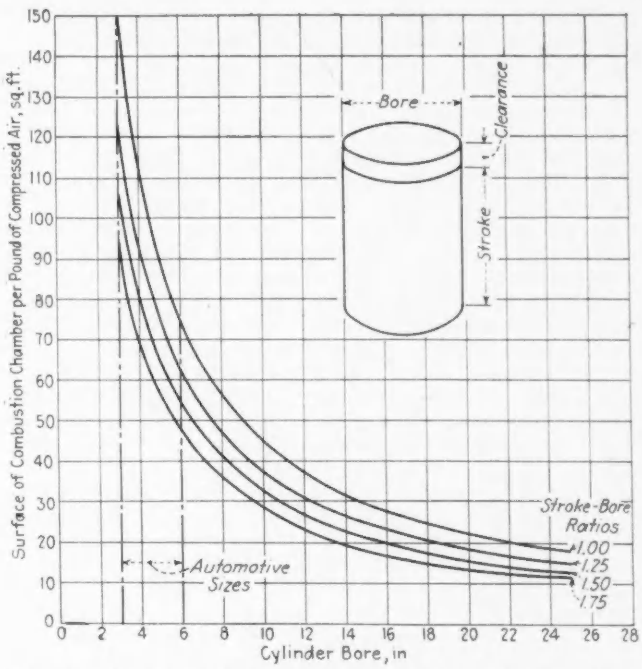


FIG. 28—SURFACE CHARACTERISTICS OF DISC-SHAPED COMBUSTION CHAMBERS

Showing How Rapidly the Ratio of Surface to Content Rises for Small-Bore Cylinders. Computed for Free-Air Density of 0.0573 Lb. per Cu. Ft. and a Compression Ratio of 13.5:1

Nature of Engine Changes in Small Sizes

JULIUS KUTTNER:—Time will not permit answering all the excellent contributions that have been made in the discussion. I recognize as an apparent defect in my paper that it reads as though I were trying to make out a definite case for particular types of engine. This is merely because the method of appraisal that I have outlined has been applied first to the engines used as examples. If this method gives a reliable index of automotive Diesel performance, it will stand on its merits regardless of the examples by which it is demonstrated.

Everyone will appreciate Mr. Vincent's penetration in questions of Diesel technology. However, I believe that the engines which he cited are not strictly in the automotive class. My analysis and the conclusions drawn from it have no bearing on 20 x 20-in. engines or even on 6 x 7-in. engines. I know that such engines maintain their torque at low speed. As automotive engineers, we must consider engines of 4½ or at the most 5-in. bore, in which the conditions are decidedly different. Whether the torque and the air capacity can be maintained with the open chamber in smaller engines as well as Mr. Vincent has undoubtedly maintained them in his larger engines is a question, because the ratio between surface and volume in the combustion chamber begins to be a predominating factor only in engines of less than 6-in. bore.

[12] M.S.A.E.—Vice-president and general manager, Hill Diesel Engine Co., Lansing, Mich.

[13] M.S.A.E.—Research engineer, Chrysler Corp., Detroit.

To illustrate the decisive effect of surface-volume ratio in Diesel-engine combustion chambers of the automotive size range, I have plotted the curves in Fig. 28. From this it is apparent that automotive Diesel engines, dealt with in my paper, may have from 7 to 10 times as many square feet of chamber surface per pound of compressed air in the chamber as have the non-automotive Diesel engines that Mr. Vincent has injected into this discussion. I cannot recognize the validity of Mr. Vincent's criticisms based on engines of 6¾-in. bore and larger. We will not retrogress to the one-cylinder car; rather, we need to use many small cylinders. The same criticism applies in some measure even to the engines on which I have reported, because they too have cylinder dimensions too large for the six and eight-cylinder engines of the modern automotive vehicle. Mr. Vincent's misapprehension is typical of recent Diesel-development history, a feature of which is rigid insistence that little Diesels act just like big ones. Some time will elapse before automotive engineers in general will squarely meet the fact that the Diesel engine undergoes a mutation of species when its dimensions are proportionately reduced.

To meet the issue in Mr. Guernsey's discussion is impossible because he too ignores the vital matter of cylinder dimensions, omitting to give the bore and stroke of the engines he has in mind. I am little inclined to dispute the statements he made, because undoubtedly they apply to some size of Diesel engine. I seriously question, however, whether his remarks have anything to do with the type of Diesel engine that is of primary interest to this Society.

Mr. Guernsey's reference to the Ringleman smoke charts is interesting, but I cannot recollect ever having seen them used except with the sky as a background. The exhaust pipes of Diesel engines undergoing dynamometer tests would have to be led to the top of the building, and I do not see any chance of using the smoke chart on the road.

With reference to Mr. Matthews' discussion, I call attention to the fact that the purpose of my paper was not primarily to decide the merits of one type of Diesel in favor of another, but to show how computations of air capacity as a function of rotative speed might be of assistance in reaching such decisions with a smaller margin of probable error. Specific types of Diesel engine were mentioned in the paper to illustrate the workings of the method of appraisal, rather than on account of their own intrinsic interest.

Mr. Hill's experience shows an interesting example of variation in combustion capacity as a function of speed. I hope that some time he can tell us how much air gets into action when he uses only one spray, and how much is utilized when both of them are working.

An Aid in Proportioning Engines

In reply to Mr. Staley's question on my formula for cylinder horsepower, I might say that this was developed to simplify the work of proportioning a series of engines of a given design so that all of them should be similarly rated with respect to mean pressure and mean piston speed. To show the effect of reducing stroke-bore ratio, only a few cylinder sizes need to be worked out, keeping fixed values for mean pressure and piston speed, the latter figure being halved for a four-cycle engine. A 6 × 6-in. 2000-r.p.m. engine, for instance, would develop 42.9 b.hp. per cylinder with a piston speed of 2000 ft. per min. and a brake mean effective pressure of 100 lb. per sq. in. spread out over two revolutions. If now the stroke-bore ratio be changed to 1.5 by reducing the bore, the output of the cylinder falls to 19.1 b.hp. per cylinder, which is in accordance with the formula.

Mr. Staley's opinion that pocketing of combustion air does not matter is justified for the more orthodox Diesel engines, in which a substantial proportion of the fuel is burned at constant pressure. However, when the total time of combustion is reduced to a few thousandths of a second, every effort must be made to burn the greatest possible percentage of the fuel as close to the dead center as possible. Pocketing interferes with the attainment of this object more as the size of the cylinder decreases and the rotative speed increases. The automotive Diesel engine can be considered more satisfactorily as working on the constant-volume than on the constant-pressure cycle. Light-load operation naturally mitigates the adverse effect of pocketing.

Usefulness of the Combustion Coefficient

Reference to the text of the paper will help to clear up any obscurity about the meaning of the combustion coefficient. I tried to emphasize that good chemical performance, expressed in terms of the ratio of quantity of air reacting chemically with the fuel to the available air, is in itself without interest to the engine designer. Therefore, instead of measuring performance in terms of the quantity of air that is chemically utilized—this being the well-known excess-air coefficient—I have followed Dr. Loschge's procedure of setting up a standard of reference for air quantity which is of more significance to the engine designer. However, I do not follow Dr. Loschge or Mr. Staley in considering this standard of reference to be identical with the more common excess-air coefficient derived from chemical theory, for the following reasons:

More air always will unite chemically than would be needed solely for *power* combustion, and for that reason the chemist always will report a greater degree of air utilization in a Diesel engine than would be reported by the thermodynamic analyst, the latter basing his computations on combustion occurring entirely at constant volume and at constant pressure. Obviously, some combustion also occurs under conditions that are less favorable for power production. The purpose of the combustion coefficient is to take these less favorable conditions into account and to use them as a rational basis for comparing various Diesel systems. The fact that a difference exists between the reciprocal of the excess-air coefficient and the combustion coefficient makes the procedure possible.

One element in Mr. Staley's apparent discouragement with the capabilities of combustion engineers may be due to their persistent disregard for the effect of absolute cylinder size on Diesel-engine technology. Not long ago obtaining a 30 x 45-in. Diesel cylinder was thought possible by the simple method of photostatically enlarging the drawings of a 10 x 15-in. cylinder. We are now witnessing attempts to reverse that process to obtain automotive-size cylinders. Some time may be needed to convince engineers that this apparently innocent process is almost sure to produce not only quantitative but also qualitative transformations. However, once the fact is accepted, the commercial realization of the automotive Diesel should not be slow in following.

The paper was intended to describe a sort of stethoscope for determining the state of health of the various automotive Diesel-engine systems now claiming to be robust enough to stand the hard knocks of commercial application. I am indebted to the discussers for the careful thought they have given to the paper. Apparently, however, they immediately began using the stethoscope on the various patients under their care, without paying much attention to the mechanics of the new instrument. Although this tacit endorsement of my device is gratifying, I look forward ultimately to a more searching criticism of its elements.

Engineering Aspects of the Modern Autogiro

Aeronautic Meeting Paper

By Agnew E. Larsen

HEREIN is presented for the first time a technical analysis of many of the fundamental engineering features of the development of the Autogiro by the engineering departments of the parent American company and its licensees. Intensive study is still being given to both the aerodynamic and the structural improvement of the rotor and also to other component elements. Attention is given in the paper to many of the developments that have contributed to the present engineering status of the machine in this Country.

Phases of the subject discussed and analyzed are the aerodynamic relationships existing in the three or four widely different combinations of rotor and fixed wing and the longitudinal balance and stability of these several types of Autogiro to determine the extent of displacement of the center of gravity that is possible without impairing the behavior of the machine in slow forward speed or nearly vertical descent, while still maintaining longitudinal stability at high speed.

The voluminous data presented show some of the engineering aspects of the latest craft and suggest the great volume of detail development work that has been involved in establishing the present standard of practice as regards the aerodynamic relationships of the rotor, fixed wing, tail surfaces and other elements.

Flight tests of pressure distribution on the fixed wings and further studies that are being conducted as to the influence of aspect ratio of the fixed wings on efficiency of the machine, of lift and thrust vectors on the rotor and of longitudinal balance and stability of new types developed, particularly with increase of gross load, promise the development of further improvements in efficiency, performance and utility.

THE National Aircraft Show this year marks the anniversary of the delivery of the first commercial Autogiro in Detroit in February, 1931. Since then this latest type of vehicle has taken its definite place among the other forms of aircraft. Through the Society and other like organizations, the writer has had an opportunity to acquaint various groups of the aircraft industry and others, at general and local meetings, with the progress that has been made in the development of this craft. Aside from a general statement[2] by Juan de la Cierva, and complete chronological reference to the many researches and developments that have been made by the engineering department of the Autogiro Co. of America and its licensees, no technical presentation has ever been given on these occasions. The Engineering Theory of the Autogiro, by Señor Cierva, hereinafter referred to as the Theory, is the basis on which the Autogiro company and its licensees do all engineering.

In the following discussion a technical analysis of many of the fundamental engineering features of the development of the machine will be made. Intensive studies are now being directed toward improvements in the rotor, both in the aerodynamic and structural phases. Until these have been completed and verified, these developments will not be made available on commercial Autogiros.

While the engineering of the craft is commonly thought of as being confined to its rotor alone, experience has shown that much of the modern development has been directed to its other components; in fact, the engineering departments of the Autogiro Co. of America and its licensees have made many studies and special researches into every phase of the complete machine and progress has been made in every direction. Attention will be directed in this paper to many of these technical developments, which have contributed much toward the development of the machine in this Country.

In a paper[3] presented by the writer before the Society at Cleveland last September, the following very encompassing paragraphs disposed of these important studies in rapid succession. This subject matter is precisely that which will be developed in full detail herein.

> Thus, the aerodynamic relationships existing in the three or four widely different combinations of rotor and fixed wing were studied assiduously from the following points of view: first, the distribution of lift between the rotor and the fixed wing; second, corrections to slopes of lift curves due to aspect ratio; third, influence of aspect ratio of the fixed wing on efficiency; fourth, study of the lift or thrust vectors on the rotor through a wide range of speeds; fifth, effect of lateral inclination or offset of the rotor axis on stability of the craft; sixth, a thorough study of longitudinal balance and stability of these various types of Autogiro to determine the permissible displacement of the center of gravity without impairing the behavior of the machine in its various slow forward speeds or nearly vertical descent, or sacrificing longitudinal stability at high speed.
>
> In this study, the effect of the relative location of the center of gravity and the center of rotation of the rotor, the location and area of the fixed wing, the location and area of the tail, the position and inclination of the engine thrust were all analyzed empirically, and this has resulted in satisfactory coefficients and factors governing each of these complex variables in individual Autogiro designs. Thus, the fixed-wing and tail-area stabilizing coefficients and the correct control-area coefficients have been derived, all of which work contributes to the production of Autogiros of much better performance and control.

Lift Distribution between Fixed Wing and Rotor

To obtain a general law of variation in distribution of lift between the fixed wing and the rotor, a series of numerical examples, in which the dimensions affecting distribution were varied, were solved. The data for these computations were obtained from the Theory.

The first example is one in which the fixed-wing area and the rotor diameter are constant, the solidity being varied through a range that will cover any practical Autogiro rotor. For this example, the fixed-wing area

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[1] Chief engineer, Autogiro Co. of America, Inc., Willow Grove, Pa.

[2] See S.A.E. JOURNAL, September, 1929, p. 204.

[3] Progress of Autogiro Development, not published in S.A.E. JOURNAL.

TABLE 1—DETERMINATION OF FIXED-WING AND ROTOR CHARACTERISTICS FOR FIXED-WING AREA OF 90 SQ. FT., WITH ASPECT RATIO OF 9 AS IN THE PCA-2 AND ROTOR DIAMETER OF 45 FT.

Ω/V	Solidity σ	Induced D/L of Rotor $(L_c/\sigma)(\sigma/2)$	Angle of Downwash on Fixed Wing, Deg.	Rotor Incidence, Deg.	Fixed-Wing Incidence from 0 Lift (Corrected for Downwash), Deg.	Over-All Rotor Lift, Lb. per M.P.H.^{2}	Over-All[a] Wing Lift, Lb. per M.P.H.^{2}	Combined Over-All Lift, Lb. per M.P.H.^{2}	Lift Carried by Rotor, Per Cent
1.5	0.055	0.00401	0.220	—2.09	+1.69	0.0652	0.0297	0.0949	68.7
	0.070	0.00511	0.293	—1.98	+1.727	0.0829	0.0306	0.1135	73.1
	0.085	0.00621	0.356	—1.88	+1.764	0.1008	0.03128	0.13208	76.2
	0.100	0.00730	0.419	—1.80	+1.781	0.1186	0.03155	0.15015	79.0
	0.115	0.00840	0.469	—1.73	+1.801	0.1364	0.0319	0.1683	81.1
	0.130	0.00950	0.544	—1.66	+1.796	0.1544	0.0318	0.1862	82.9
6.0	0.055	0.0841	4.824	+10.85	+10.026	1.368	0.1778	1.5458	88.6
	0.070	0.1072	6.154	+12.08	+9.926	1.74	0.1756	1.9156	90.9
	0.085	0.130	7.469	+13.27	+9.801	2.11	0.1736	2.2836	92.4
	0.100	0.153	8.80	+14.50	+9.700	2.484	0.1717	2.6557	93.6
	0.115	0.176	10.138	+15.65	+9.512	2.86	0.1683	3.0283	94.5
	0.130	0.199	11.479	+16.88	+9.401	3.23	0.1665	3.3965	95.1

[a] Slope of lift curve of Göttingen 429 airfoil, corrected to aspect ratio of 9, is 0.0001982, from New York University wind-tunnel test No. 422.

is taken as 90 sq. ft. and the rotor diameter as 45 ft., which are dimensions in use on the PCA-2 Autogiros. The pitch angle θ of the rotor is taken as 4 deg.

The steps in determining the relative distribution are the computation of the induced-drag-lift ratio of the rotor, the mean angle of downwash on the fixed wing, the rotor and fixed-wing incidences, the rotor and fixed-wing over-all lifts in pounds per mile per hour squared, and the total lift, which is the sum of the lifts of the wing and the rotor. The percentage of lift car-

Symbols Used in the Paper

Dimensions of the Autogiro

A = aspect ratio of the fixed wing

b = number of rotor blades

c = chord of rotor blade, inches

d = distance from axis of rotor to horizontal articulation pin, inches. (d is also used conventionally to indicate differential)

h_1 = distance between center of gravity and plane of rotor, inches

L_1 = perpendicular distance between rotor thrust line (constructional) and center of gravity, inches

L_{1c} = value of L_1 corrected for fixed-wing lift

$(L_1/h_1)_n$ = ratio for nose-heavy-balance condition

$(L_1/h_1)_t$ = ratio for tail-heavy-balance condition

m = ratio of fixed-wing area to virtual blade area

R = radius of the rotor, feet

S = total area of blades, when rectangular, square feet

θ = pitch angle of blades, from no-lift incidence, degrees

σ = solidity of rotor; in the case of rectangular blades $\sigma = S/(\pi R^2)$

Movements of the Autogiro

i = angle of incidence, measured as angle of axis of rotation to vertical, regarded as positive when axis is inclined backward, degrees

n = rotor speed, revolutions per minute

V = speed of horizontal displacement of machine, usually in miles per hour

V_0 = vertical speed in vertical descent, feet per second

v = speed of air flow through the rotor disc, feet per second

w = induced speed, when considered as constant through the disc, feet per second

β = angle between longitudinal axis of rotor blade and plane perpendicular to axis of rotation, degrees

β_0 = average value of β, degrees

ϵ = angle between average plane of rotation of articulated blades and plane perpendicular to axis of rotation, degrees

ϕ = value of ψ for which β is the maximum, radians

ψ = angular position of blade, when measured from forward position and in direction of rotation, radians

Ω = peripheral speed at rotor-blade tips, miles per hour when used in Ω/V, elsewhere, feet per second

ω = angular speed $= \Omega/R$, radians

Forces on the Autogiro

$a = dL_c/d\alpha$ for the airfoil used, assumed to be constant

D = drag, pounds

$K = (\beta_0 - \epsilon \cos \phi)/(2\,\beta_0)\ 2e$

L = lift, pounds

L_c = lift coefficient of rotor, in English absolute system

T = total thrust or reaction, pounds

W = weight of the machine, pounds

w_b = weight of one blade of the rotor, pounds

α = actual resultant incidence of an element of the blade, degrees

δ = minimum profile drag of airfoil used

ρ = density of the air

Assumptions

b = number of blades = 4

R = radius of rotor, assumed to be constant

$Z = (\rho g \sigma)\ (2\pi R^2)\ [1/(4\,w_b) - 1/T]$

$z = (\epsilon \cos \phi - \beta_0)/(2\,\beta_0)$

θ = blade-tip pitch angle = 4 deg.

σ = solidity = area of rotor blades ÷ area of rotor disc

ried by the rotor is 100 times the ratio of the over-all rotor lift to the total lift. These steps are shown in Table 1. The determination of ratio m in Table 1 is shown in Table 2, and the relation between m and the percentage of lift carried by the rotor is shown in Fig. 1.

In the second example, a rotor of 45-ft. diameter and of solidity of 0.100 is held constant, with a fixed wing of varying area but a constant aspect ratio of 9. The general method is very similar to that used in obtaining Table 1. The tabulated values are shown in Table 3, in which the angle of downwash, the rotor and fixed-wing incidence and the over-all rotor lift are used from Table 1.

In Fig. 2 the data from Table 3 are plotted to show the relationship between m and the percentage of lift carried by the rotor.

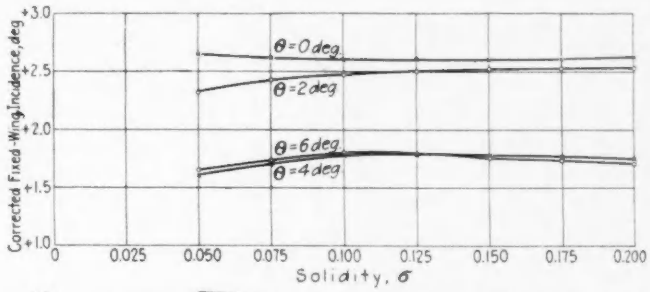
From Figs. 1 and 2, it is apparent that the percentage of lift carried by the rotor at $\Omega/V = 6.0$ (the high-angle-of-attack condition, approximately 14 deg. in present rotors) is practically a linear function of the ratio m. The different values for this condition from the two figures check reasonably closely. However, for the case of $\Omega/V = 1.5$ (the low-angle-of-attack condition, approximately -1.8 deg. in present rotors), this difference is very nearly 2 per cent for the higher values of m. This is because several variations of rotor diameter, solidity and fixed-wing area are possible, which give the same value of m. Consequently, the way recommended as most logical for finding the distribution of lift between the fixed wing and the rotor is to use the curves of Fixed-Wing Incidence Corrected for Rotor Downwash, shown in Figs. 3 and 4. These values have been computed in the same way as the fixed-wing incidence in Table 1.

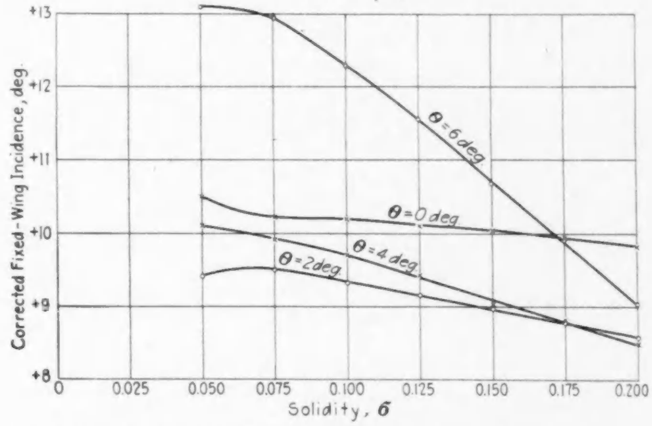
The procedure in determining the lift distribution, at $\Omega/V = 1.5$, between the fixed wing and rotor in any combination is:

(1) Determine the over-all rotor lift. In engineering units, this is the appropriate value of L_c/σ

TABLE 2—DETERMINATION OF m FOR FIXED WING OF 90 SQ. FT.

Solidity σ	Virtual Blade Area ($\pi R^2\sigma$) Sq. Ft.	Ratio m = Fixed-Wing Area ÷ Virtual Blade Area
0.055	87.4	1.03
0.070	111.3	0.807
0.085	135.2	0.665
0.100	159.0	0.566
0.115	182.8	0.493
0.130	206.8	0.435



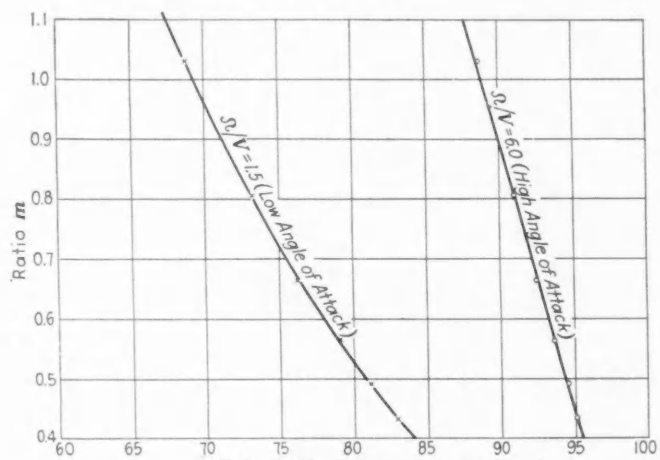


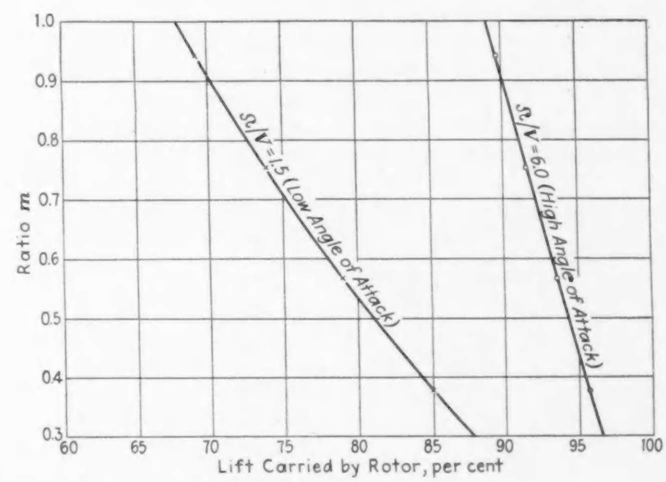
FIXED-WING INCIDENCE CORRECTED FOR DOWNWASH AT ROTOR CENTER BLADE PITCH ANGLES 0, 2, 4 AND 6 DEG. FROM NO-LIFT INCIDENCE

Fig. 3 (Above)—For Low Angle of Attack ($\Omega/V = 1.5$)
Fig. 4 (Below)—For High Angle of Attack ($\Omega/V = 6.0$)

TABLE 3—CHARACTERISTICS OF FIXED WING AND ROTOR FOR A DIAMETER OF 45 FT. AND $\sigma = 0.100$

Ω/V	Fixed-Wing Area, Sq. Ft.	Over-All Wing Lift, Lb. per M.P.H.²	Combined Over-All Lift, Lb. per M.P.H.²	Lift Carried by Rotor, Per Cent	Ratio m
1.5	60	0.0210	0.1396	85.0	0.377
	90	0.03155	0.15015	79.0	0.566
	120	0.04205	0.16065	73.9	0.754
	150	0.0526	0.1712	69.2	0.942
6.0	60	0.1145	2.5985	95.7	0.377
	90	0.1717	2.6557	93.6	0.566
	120	0.2290	2.713	91.6	0.754
	150	0.2865	2.7705	89.7	0.942





RELATIONSHIP BETWEEN RATIO m (SEE BOX) AND PERCENTAGE OF LIFT CARRIED BY THE ROTOR

Fig. 1—From Data in Table 1

Fig. 2—From Data in Table 3

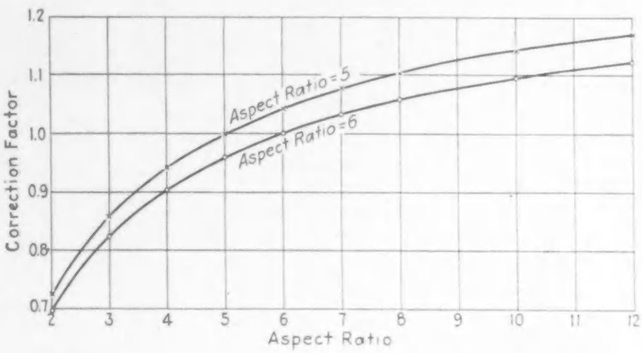


FIG. 5—CORRECTION FACTORS FOR SLOPE OF LIFT CURVE

(from Table 4 of the Theory) multiplied by σ times the disc area in square feet times 0.00511.

(2) The over-all fixed-wing lift is the incidence from zero lift (from Fig. 3) times the slope of the lift curve (corrected for aspect ratio); in engineering units, $dL_c/d\alpha$ times the fixed-wing area in square feet.

(3) The combined over-all lift is the sum of (1) and (2).

(4) The percentage of lift carried by the rotor is (1) divided by (3).

The corrected incidence of the fixed wing for $\Omega/V = 6.0$ (high angle of attack) is given in Fig. 4, and the relative distribution of lift will be determined in the same manner as for $\Omega/V = 1.5$.

The fact that in this study data are given which make possible the finding of the lift distribution for any combination of fixed wing and the rotor must not be taken to imply that any such combination can be used indiscriminately in the Autogiro. The purpose is to indicate the way in which to calculate the lift distribution for any minor variation from the dimensions recommended in the Theory, these minor variations being the result of practical considerations that often enter into the design of the machine.

Corrections to Slopes of Lift Curves for Aspect Ratio

In the foregoing discussion of the distribution of lift between the fixed wing and the rotor, the fixed-wing lift is computed in terms of incidence above zero lift, area and slope of the lift curve, corrected for aspect ratio. This last characteristic requires the greatest amount of computation, and the purpose of this study is to derive curves that will give correction factors to aid in determining the slope of the lift curve for any new aspect ratio.

American practice is to obtain wind-tunnel tests at aspect ratios of 6, whereas some Continental European practice is to obtain tests at an aspect ratio of 5. Consequently, two curves are constructed in Fig. 5, one for airfoils tested at an aspect ratio of 6, the other for those tested at 5.

Warner[4] gives the slope of the lift curve, in engineering units, as

$$\left(\frac{dL_c}{d\,\alpha}\right)_A = \left(\frac{dL_c}{d\,\alpha}\right)_\infty \frac{1}{1 + 22{,}400\left(\frac{dL_c}{d\,\alpha}\right)_\infty/(\pi\,A)} \qquad (1)$$

where

$(dL_c/d\alpha)_A$ = slope of the life curve of a section of aspect ratio A

$(dL_c/d\alpha)\infty$ = slope of the lift curve of the same section at an aspect ratio ∞

Using the above relation and calling $(dL_c/d\alpha)_A = 1$, for the aspect ratio tested, Table 4 is derived.

Influence of Fixed-Wing Aspect Ratio on Efficiency

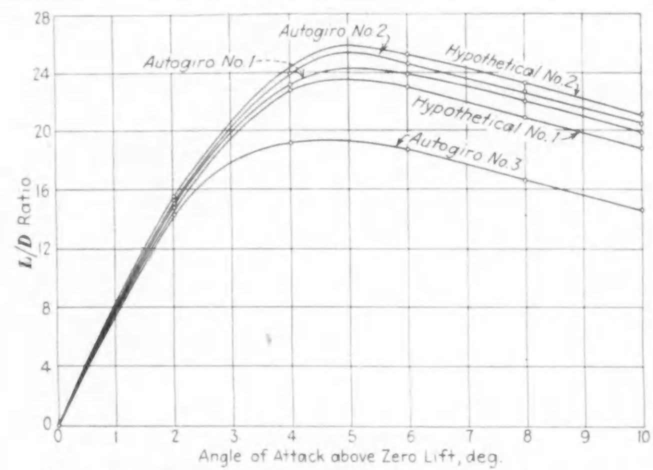
To show the effect of area and aspect ratio of the fixed wings on the over-all efficiency, the L/D ratios for the combination of fixed wing and rotor in three actual Autogiros were computed. Also computations were

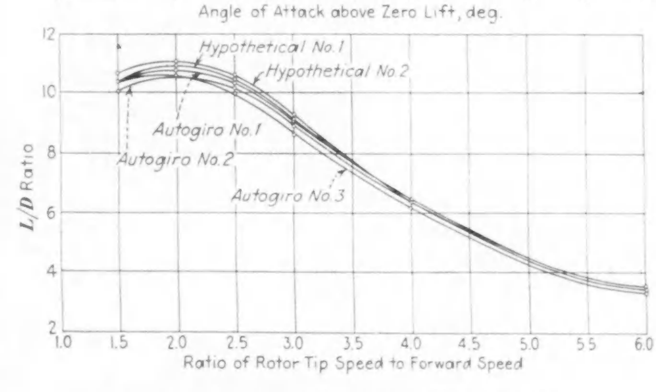
[4] See Airplane Design, by Edward P. Warner, p. 336.

TABLE 4—RATIOS OF SLOPE OF LIFT CURVE AT ASPECT RATIOS DIFFERENT FROM THAT AT WHICH THE SECTION WAS TESTED

Tested at Aspect Ratio 5		Tested at Aspect Ratio 6	
Aspect Ratio	Factor	Aspect Ratio	Factor
2	0.725	2	0.697
3	0.857	3	0.824
4	0.941	4	0.904
5	1.000	5	0.960
6	1.042	6	1.000
7	1.077	7	1.034
8	1.102	8	1.058
10	1.142	10	1.096
12	1.170	12	1.123

The curves of correction factor versus aspect ratio are shown in Fig. 5.





LIFT-DRAG CURVES FOR SEVERAL AUTOGIROS

Fig. 6 (Above)—Corrected for Aspect Ratio of Fixed Wings from Zero Lift to 10 Deg.

Fig. 7 (Below)—Over-All Ratios for Combined Fixed Wing and Rotor

DIMENSIONS OF AUTOGIROS CHARTED IN FIGS. 6 AND 7

	Area of Fixed Wing, Sq. Ft.	Aspect Ratio of Fixed Wing	Rotor Diameter, Ft.	Disc Area of Rotor, Sq. Ft.	Solidity	$dL_c/d\alpha$
Autogiro No. 1	50	9.43	37	1,075	0.1003	0.0001995
Autogiro No. 2	88	8.9	45	1,590	0.0976	0.0001982
Autogiro No. 3	100	5.2	41	1,320	0.1000	0.0001781
Hypothetical No. 1	75	8.0		1,000	0.1000	0.0001950
Hypothetical No. 2	75	10.0		1,000	0.1000	0.0001950

made for two hypothetical machines in which the fixed-wing area was $0.75\,\pi R^2\sigma$, as recommended in the Theory, with aspect ratios of 8 and 10.

All of the fixed wings were considered to be of Göttingen-429 airfoil section, the characteristics of which are given in New York University wind-tunnel test No. 422. As the data from this test show, the lift curve is practically a straight line to an angle of attack of 10 deg. As the fixed wings of the machines considered do not operate above 10 deg., corrections for aspect ratio from zero lift to 10 deg. were made to the slope of the lift curves and the drag for aspect ratio[5], with the resulting L/D curves shown in Fig. 6. As the computations outlined are familiar to engineers, they are not given here.

The next steps in the investigation were taken to determine the lift distribution between the fixed wing and the rotor, the "weighted" L/D ratios for the fixed wing and rotor, and, finally, the over-all L/D ratios for the combined fixed wing and rotor. These steps are similar to those shown in Table 1. The over-all L/D ratios for the combined fixed wing and rotor are shown in Fig. 7.

A correction to the fixed-wing L/D for downwash is necessary because the mean relative wind over the fixed wing is already distorted to the angle $\epsilon/2$ due to rotor downwash, and the effective L/D of the fixed wing with respect to the undisturbed air will be decreased.

From Fig. 7 it is observed that the efficiency with low-aspect-ratio fixed wings is relatively lower than where high aspect ratio is used. Even with the area of the low-aspect-ratio fixed wing as recommend by Cierva, the Autogiros having higher aspect ratio but less fixed-wing area are the more efficient. In the two hypothetical cases computed, the relative fixed-wing area is that recommended by Cierva. The benefits due to both correct wing area and favorable aspect ratio are shown by substantial increases in efficiency at the higher speeds.

From this investigation, it is apparent that, if the fixed-wing area is limited, the use of this small area at high aspect ratio is advisable. If no such limitation is imposed and the structural problems introduced by high aspect ratio are not too great, the use of the area recommended by Cierva at a high aspect ratio, preferably 8 or above, is advisable. These conclusions are influenced largely by considerations of the maintenance of correct rotor speed throughout the full range of flight speeds.

Many other relationships, particularly those dealing with longitudinal stability and balance, are affected by the fixed-wing-and-rotor combination. Some of these will be discussed more fully later in this paper.

Correct Location and Setting of Rotor Axis

In the attachment of the rotor to the pylon and the rest of the Autogiro, particular care must be exercised

[5] See Airplane Design, by Edward P. Warner, pp. 96 and 336.

TABLE 6—THRUST OFFSET IN PERCENTAGE OF d

	Ω/V	β_0, Deg.	$\epsilon \cos\phi$, Deg.	$\epsilon \cos \phi - \beta_0$, Deg.	$z = (\epsilon\cos\phi - \beta_0)/2\beta_0$	$2z$	Offset in Percentage of $d = 2z + \frac{1}{2}$
$\beta_0 = 4$ Deg. at $\Omega/V = 1.5$	1.5	4.0	7.7	3.7	0.463	0.926	96.3
	2.0	3.9	6.5	2.6	0.333	0.666	83.3
	2.5	4.1	5.3	1.2	0.146	0.292	64.6
	3.0	4.3	4.3	0	0	0	50.0
	4.0	4.7	2.9	—1.8	—0.191	—0.382	30.9
	6.0	5.3	2.0	—3.3	—0.311	—0.622	18.9
$\beta_0 = 10$ Deg. at $\Omega/V = 1.5$	1.5	10.0	7.7	—2.3	—0.115	—0.23	38.5
	2.0	9.8	6.5	—3.3	—0.168	—0.336	33.2
	2.5	10.2	5.3	—4.9	—0.240	—0.48	26.0
	3.0	10.8	4.3	—6.5	—0.300	—0.60	20.0
	4.0	11.8	2.9	—8.9	—0.377	—0.754	12.3
	6.0	13.1	2.0	—11.1	—0.423	—0.846	7.7
$\beta_0 = 20$ Deg. at $\Omega/V = 1.5$	1.5	20.0	7.7	—12.3	—0.308	—0.616	19.2
	2.0	19.5	6.5	—13.0	—0.333	—0.666	16.7
	2.5	20.5	5.3	—15.2	—0.371	—0.742	12.9
	3.0	21.6	4.3	—17.3	—0.400	—0.80	10.0
	4.0	23.5	2.9	—20.6	—0.438	—0.876	6.2
	6.0	26.2	2.0	—24.2	—0.462	—0.924	3.8

in the proper corrective settings which adequately compensate for the movement of rotor thrust with increased speed. To this end, numerous studies have been made of the direction and extent of the inclination and offset of rotor thrust for various speeds in machines of all sizes. From results obtained, any new rotor can be placed with full consideration of longitudinal stability and longitudinal and lateral balance throughout the range of flight speeds obtainable.

Quantitative studies were then made of the rolling moments due to this tilt and inclination of the thrust line of the rotor on several Autogiros to ascertain the effect of these forces on lateral stability and control. Further studies were made of the influence of the combined rolling moments from the rotor and the torque reactions from the propeller, particularly with the view of having the correct direction of rotation for pusher planes to propeller-torque reaction which is reversed in direction.

Lift or Thrust Vectors of the Rotor

A study of the lift or thrust vectors of the rotor through a wide range of speeds has been made to establish the maximum and minimum of rotor thrust-line tilt and offset. To obtain these enough values must be computed to give a set of curves from which the "blanket" conditions, or values, can be taken. Several assumptions are necessary to solve the formulas, but an effort is made to choose the values of these assumptions so that all normal Autogiros will fall within the limits that are concluded to be critical.

All computations are based upon relationships established by Cierva in the Theory. In this study two conditions are found which, while not strictly accurate for each individual case, are close enough to give designs that err, if at all, on the conservative side. They are high angle of attack and low angle of attack, consid-

TABLE 5—CONING AND FLAPPING ANGLES
(Tables to Which References Are Made Are in Cierva's Theory)

Ω/V	L_c/σ (Table 4)	$(\Omega/V)^2$	$1/(L_c/\sigma)$	$(\Omega/V)^2[1/(L_c/\sigma)]$	β_0: For 4 Deg. $(Z_1 = 61.7)^a$ Deg.	β_0: For 10 Deg. $(Z_2 = 154.1)^a$ Deg.	β_0: For 20 Deg. $(Z_3 = 308.2)^a$ Deg.	$\epsilon \cos \phi$ (Table 10) Deg.
1.5	0.146	2.25	6.85	15.41	4.0	10.0	20.0	7.7
2.0	0.254	4.0	3.94	15.77	3.0	9.8	19.5	6.5
2.5	0.416	6.25	2.405	15.04	4.1	10.2	20.5	5.3
3.0	0.630	9.0	1.588	14.30	4.3	10.8	21.6	4.3
4.0	1.222	16.0	0.818	13.10	4.7	11.8	23.5	2.9
6.0	3.06	36.0	0.327	11.77	5.3	13.1	26.2	2.0

[a] From the Theory:

$$Z = \beta_0\,(\Omega/V)^2\,[1/(L_c/\sigma)]$$
$$Z_1 = 4 \times 15.41 = 61.7$$
$$Z_2 = 10 \times 15.41 = 154.1$$
$$Z_3 = 20 \times 15.41 = 308.2$$

TABLE 7—FEATURES AFFECTING ROLLING MOMENT FROM ROTOR

	Autogiro PCA-2		Autogiro PAA-1	
Item	$\Omega/V=2$	$\Omega/V=6$	$\Omega/V=2$	$\Omega/V=6$
Gross Weight, lb.	3,000	3,000	1,750	1,750
Rotor Thrust, lb.	2,460	2,770	1,436	1,614
Rotor Speed, r.p.m.	137.5	126.2	153.8	142.0
β_0, deg.	5.15	7.00	4.86	6.48
$\epsilon \cos \phi$, deg.	5.3	1.6	5.3	1.6
$\epsilon \sin \psi$, deg.	6.96	1.92	6.73	1.82
$\beta_0 + \epsilon \sin \psi$, deg.	12.11	8.92	11.59	8.30
$\beta_0 - \epsilon \sin \psi$, deg.	− 1.81	+ 5.08	− 1.87	+ 4.66
Horizontal Offset of Center Line of Pin, d in.	3⅜	3⅜	2¾	2¾
Rotor Inclination, deg.	2½ L.	2½ L.	1 L.	1 L.
Rotor Offset	6-lb. ballast on tip of right wing		Pylon offset 1 in. to right of plane of symmetry	

eration of which will cover all intermediate conditions. No attempt has been made in previous designs to formulate conditions. The tilt and offset of the rotor thrust line occurs longitudinally and laterally simultaneously. In other words, the rotor thrust line may be offset toward the forward horizontal articulation and at the same time offset laterally toward the left horizontal articulation. This study recognizes only the longitudinal movement, as the lateral movement is relatively less important.

Since the average coning angle β_0 is affected by solidity, blade weight, pitch angle and other factors, a wide range will be investigated. The normal range of β_0 is from 6 to 12 deg. We shall compute for values of $\beta_0 =$ 4, 10 and 20 deg., which will cover all probable combinations of conditions (See Tables 5 and 6).

Values of thrust tilt and thrust offset will be computed for $\Omega/V = 1.5$, 2, 2.5, 3.0, 4.0 and 6.0 for each value of β_0. This range of Ω/V is shown by Cierva as the greatest range through which the thrust tilt and offset will be noticeably affected.

From the Theory we see that the coning angle β_0 varies as a function of Ω/V, since

$$\beta_0 = (\rho g \sigma)\ (2\pi R^2)\ \left(\frac{1}{4w_b} - \frac{1}{T}\right) \left(\frac{1}{\left[(\Omega/V)\sqrt{\left(\frac{1}{L_c/\sigma}\right)}\right]^2}\right) \quad (2)$$

For any Autogiro flying under given conditions, the first three terms may be replaced by a constant factor.

Let
$$Z = (\rho g \sigma)\ (2\pi R^2)\ [1/(4W_b) - 1/T]$$
then
$$\beta_0 = Z \frac{1}{\left[\Omega/V\sqrt{\left(\frac{1}{L_c/\sigma}\right)}\right]^2} \quad (3)$$

To find the value of the constant Z, the assumed value of β_0 will be substituted at $\Omega/V = 1.5$. Knowing the value of Z, β_0 can be computed for the complete range in function of Ω/V; therefore

$$Z = \beta_0\ (\Omega/V)^2 \frac{1}{L_c/\sigma} \quad (4)$$

The thrust offset of the rotor is, from the Theory:

$$\text{Offset} = (K + d)/2 \quad (5)$$

in which

$$K = -\ (\beta_0 - \epsilon \cos \phi)/(2\,\beta_0)\ 2\,d$$

Let

$$z = -\frac{\beta_0 - \epsilon \cos \phi}{2\,\beta_0} = \frac{\epsilon \cos \phi - \beta_0}{2\,\beta_0}$$

which gives

$$K = 2\,dz$$

$$\text{Thrust offset} = (K + d)/2 = (2\,dz + d)/2 = [d\ (2\,z + 1)]/2$$

Offset in percentage of $d = [d\ (2\,z + 1)/2]/d = (2\,z + 1)/2$

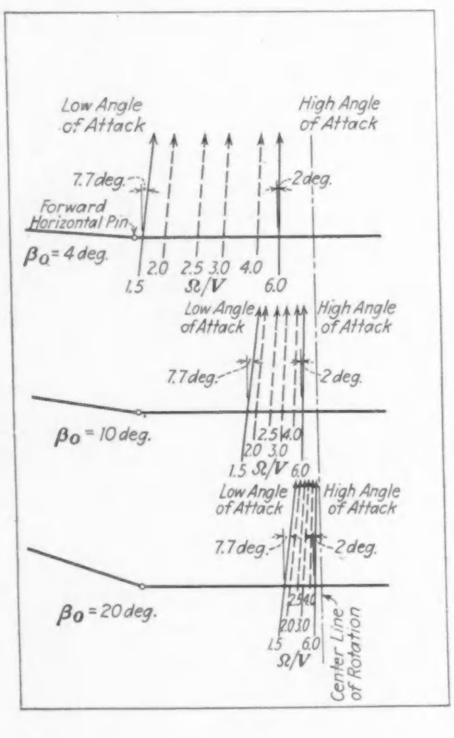


FIG. 8—GRAPHICAL REPRESENTATION OF POSITION AND DIRECTION OF ROTOR THRUST

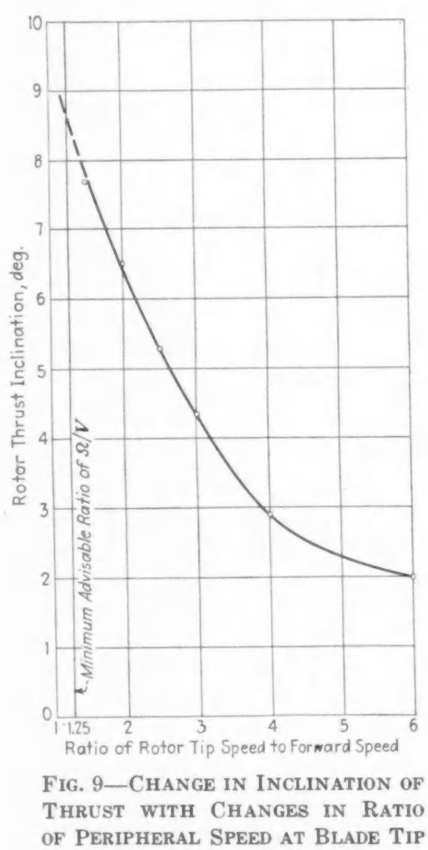


FIG. 9—CHANGE IN INCLINATION OF THRUST WITH CHANGES IN RATIO OF PERIPHERAL SPEED AT BLADE TIP TO SPEED OF FORWARD MOTION

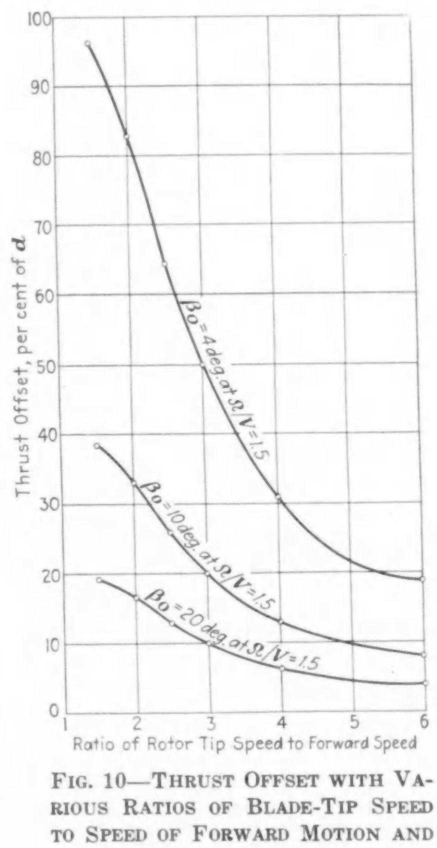
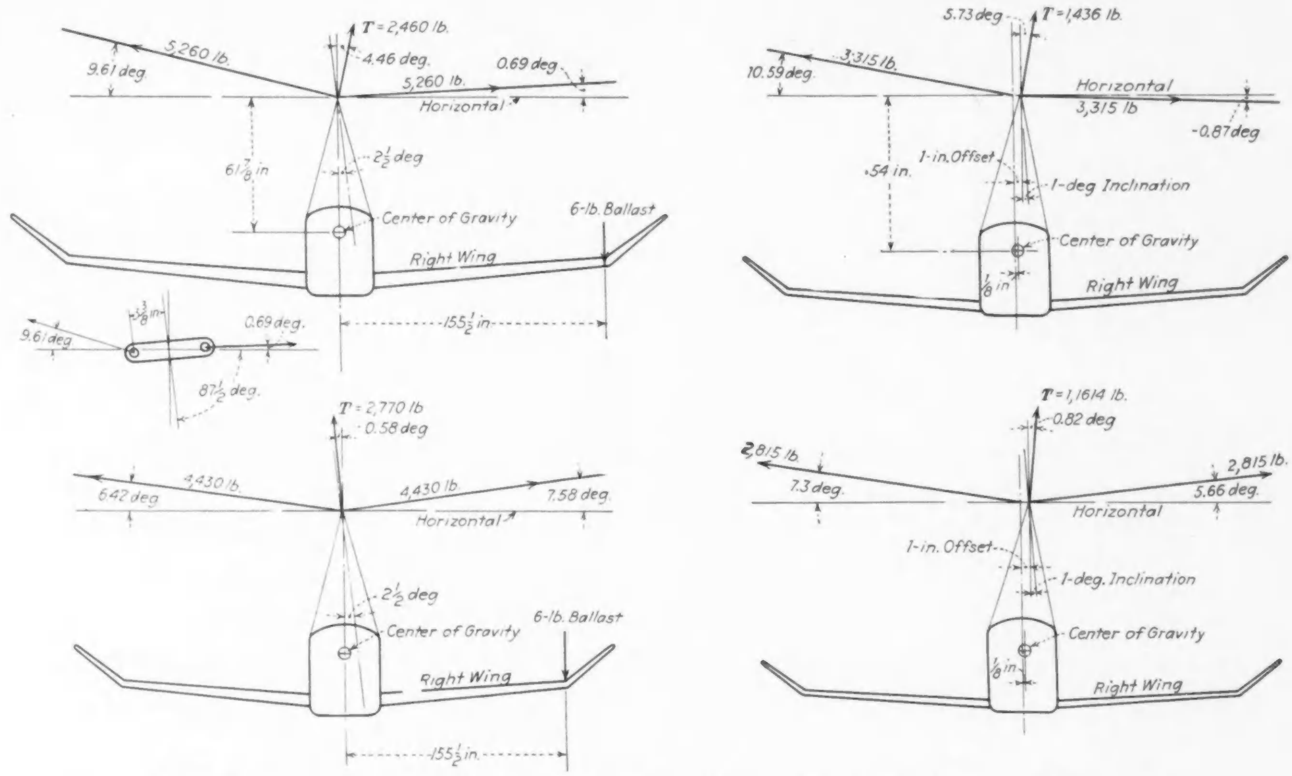


FIG. 10—THRUST OFFSET WITH VARIOUS RATIOS OF BLADE-TIP SPEED TO SPEED OF FORWARD MOTION AND VARIOUS ANGLES OF BLADE



FORCES ACTING TO PRODUCE ROLLING MOMENTS IN TWO AUTOGIROS AT HIGH AND LOW SPEEDS
For Data See Tables 7 and 8

Fig. 11—The PCA-2, $\Omega/V = 2.0$
Fig. 12—The PCA-2, $\Omega/V = 6.0$
Fig. 13—The PAA-1, $\Omega/V = 2.0$
Fig. 14—The PAA-1, $\Omega/V = 6.0$

The total thrust on a rotor is inclined upward and backward, with relation to the axis of rotation, by angles equal to the longitudinal flapping angle $\epsilon \cos \varphi$, as stated in the Theory. The computations for thrust offset are shown in Table 6. The position and direction of the total thrust are represented graphically in Fig. 8 for all conditions computed.

Fig. 9 indicates the change in thrust inclination with changes in Ω/V ratio. Note that, at the maxmium advisable Ω/V ratio $= 1.25$, the inclination is approximately 9 deg.; also that at the other end of the range the inclination approaches zero, which we know it does in vertical descent ($\Omega/V = \infty$) since no flapping occurs in that attitude.

Fig. 10 shows the thrust offset with various values of Ω/V and β_0. From inspection it is apparent that the limits of thrust offset lie at 0 and 100 per cent of d.

The following applications of load will cover the design conditions required to give satisfactory results in the design of normal Autogiros:

(1) For high angle of attack ($\Omega/V > 6$), the rotor thrust is coincident with the center line of rotation. Inclination and offset equal zero.
(2) For low angle of attack ($\Omega/V = 1.5$), the rotor-thrust passes through the forward horizontal pin and is inclined upward and backward at 10 deg. to the axis of rotation.

These design conditions cover all flight conditions to and including $\Omega/V = 1.25$ and a coning angle of $\beta_0 = 4$ deg., both of which are very conservative in the light of present designs.

Quantitative Study of Rolling Moments

The quality of rolling moments resulting from both the inclination and the tilt of the rotor thrust line, due to flapping, has been known for some time. To have a better idea of the magnitude of these rolling moments, the following study was made for the high-speed and the low-speed flight conditions of the PCA-2 and the PAA-1 Autogiros.

The average coning angle was computed from the known weights of the machine and the blade and the relations as set forth in the Theory. The computations of the lateral flapping angles were exactly as set forth in the Theory. The tabulated values of the different features entering into the computation of rolling moments due to flapping appear in Table 7.

TABLE 8—ROLLING MOMENTS OF TWO AUTOGIROS CAUSED BY FLAPPING, ROTOR OFFSET AND WING BALLAST

Moment Due to	*PCA—2* $\Omega/V = 2.0$	*PAA—1* $\Omega/V = 2.0$
Inclination of Thrust	61.4375 × 2,460 × sin 4.46 deg. = + 11,720 lb-in.	+ 1,436 × 54 × sin 5.73 deg. = + 7,730 lb-in.
Offset of Horizontal Pins	5,260 × 3⅜ × sin 1.81 deg. + 5,260 × 3⅜ × sin 12.11 deg. = + 4,274 lb-in.	+ 2¾ × 3,315 × sin 1.87 deg. + 2¾ × 3,315 × sin 11.59 deg. = + 2,134 lb-in.
Ballast in Right-Wing Tip	6 × 155.5 = 933 lb-in.	— 1,436 × 0.875 × cos 5.87 deg. = — 1,250 lb-in.
Total Moment	+ 11,720 + 4,274 + 933 = + 16,927 lb-in.	+ 7,730 + 2,134 — 1,250 = + 8,614 lb-in.
	$\Omega/V = 6.0$	$\Omega/V = 6.0$
Inclination of Thrust	— 61.4375 × 2,770 × sin 0.58 deg. = — 1,700 lb-in.	+ 1,614 × 54 × sin 0.82 deg. = + 1,264 lb-in.
Offset of Horizontal Pins	— 4,430 × 3⅜ x sin 5.08 deg. + 4,430 × 3⅜ × sin 8.92 deg. = + 974 lb-in.	— 2¾ × 2,815 × sin 4.66 deg. + 2¾ × 2,815 × sin 8.3 deg. = + 484 lb-in.
Offset of Pylon Center Line	+ 6 × 155.5 = + 933 lb-in.	— 1,614 × ⅞ × cos 0.82 deg. = — 1,413 lb-in.
Total Moment	— 1,700 + 974 + 933 = + 207 lb-in.	= + 335 lb-in. + 1,264 + 484 — 1,413

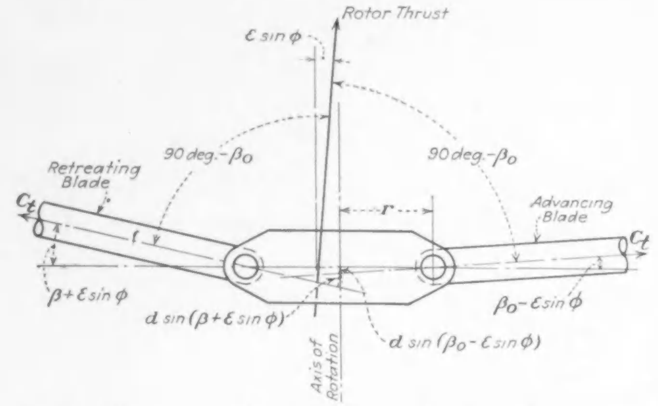


FIG. 15—CAUSES OF TOTAL ROLLING MOMENT PRODUCED BY THE ROTOR

Inclination of Rotor Thrust Causes Part of the Moment. Centrifugal Tension of Opposite Rotor Blades Acting Asymmetrically, Because of Offset of Rotor Reaction, Causes an Additional Moment of $C_t[d \sin(\beta_0 + \epsilon \sin \phi) - d \sin(\beta_0 - \epsilon \sin \phi)]$

Forces acting at the different flight conditions on these two machines are shown in Figs. 11 to 14. The rolling moments due to flapping, rotor offset and ballast are as given for each of the machines in Table 8, a rolling moment tending to drop the right wing being considered positive.

The rolling moments due to the rotor are then

Machine	Speed, M.P.H.	$\Omega/V = 2$, Lb-In.	Speed, M.P.H.	$\Omega/V = 6$, Lb-In.
PCA-2	110.0	+ 16,927	34.0	+ 207
PAA-1	101.0	+ 8,614	31.0	+ 335

This investigation shows the magnitude of the rolling moments and the different speeds at which they occur, which will in turn give an indication of the amount of lateral control that is available to overcome these induced rolling moments.

Directions of Rotor and Propeller Rotation

In many of the earlier models of Autogiro the direction of rotation of the rotor and the propeller was such that an excessive rolling moment was encountered, especially when the flapping angles were more pronounced with increase of speed. Considerable lateral adjustment, provided for by controllable pylons, was necessary to maintain lateral balance in fast forward flight with power on, and this adjustment had to be decreased as soon as the power was reduced. Since 1928, the directions of rotation of the engine and the rotor have been the same when viewed from the pilot's seat, and the improved flying characteristics of the tractor planes have permitted the elimination of the laterally controlled pylon.

The belief at first was that this interrelation of the direction of rotation of the rotor and the propeller was necessitated by an interaction of the propeller slipstream and the rotor downwash, in function of race rotation. Further investigation has shown, however, that it is much more logical to ascribe the necessity of this rotor-propeller arrangement to the torque reaction of the propeller and a rolling moment from the rotor at high speeds, as described below.

The well-known torque reaction from a propeller gives a rolling moment that is opposite to the direction of rotation of the propeller. Given the engine power and propeller speed in revolutions per minute, the actual torque can be determined by a simple computation.

In a tractor, besides the tendency of the torque reaction of American engines to roll the machine to the left, a secondary force tends to yaw the machine in the same direction as that induced by the roll. This secondary force is contributed by the race rotation of the slipstream causing the air to strike the left side of the vertical surfaces with a small positive incidence. This tends to force the tail of the machine to the right, producing a yaw to the left.

The rolling moment from the rotor is zero in vertical descent, is practically zero at very low forward speeds and increases gradually until it reaches the maximum at the highest forward speed. This moment is caused by the fact that, with forward speed of any magnitude, the advancing blade is relatively lower than the retreating blade, owing to lateral flapping of the rotor blades. With an average coning angle of 6 deg. and a lateral flapping angle of 6 deg., the advancing blade would be level and the retreating blade 12 deg. above the horizontal, neglecting any lateral inclination of the pylon. The total rolling moment from the rotor can be divided into two parts, one of which is caused by the centrifugal tension of individual opposite blades not acting symmetrically (See Fig. 15), and the other by the inclination of the rotor thrust (See Figs. 15 and 16).

It may be seen from Fig. 16 that the rolling moment due to the inclination of the rotor thrust can be corrected for by inclining the rotor, and that, when this thrust passes through the center of gravity of the machine, the rolling moment is zero.

Fig. 15 shows the lateral offset of the rotor reaction, as well as its inclination. On the latest American Autogiro, the PAA-1, both the inclination and the offset are corrected for by the location of the pylon. Apparently, from Fig. 15, as long as the machine has forward speed and a distance d between the center line of rotation and the center line of the horizontal pin, a rolling moment will be caused by the rotor. This rolling moment has been counteracted on the PAA-1 by locating the pylon 1 in. off the plane of symmetry.

From Fig. 16, showing an Autogiro with the propeller turning in the same direction but with the rotor turning

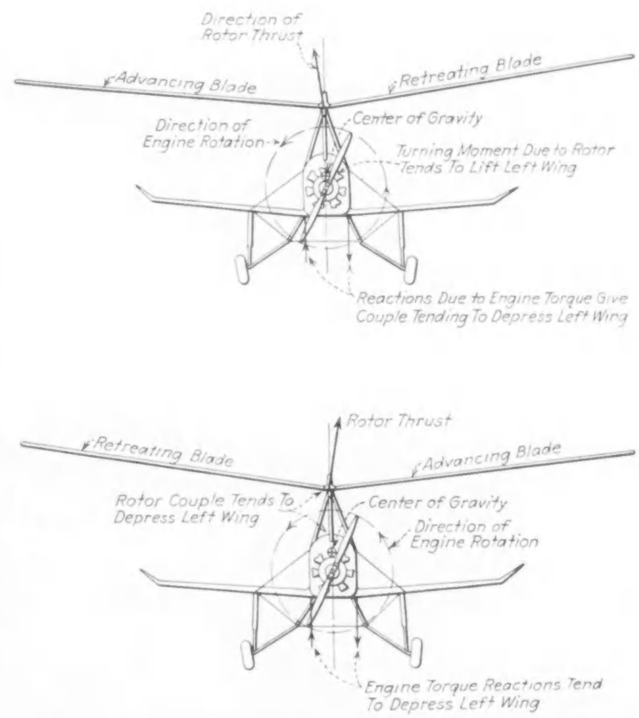


FIG. 16—TENDENCY OF AUTOGIRO TO ROTATE LATERALLY

Front Elevations in Forward Flight Showing (Above) Counter-Clockwise and (Below) Clockwise Rotation of Rotor

in opposite directions in the two drawings, the fact can readily be seen that in both cases the propeller torque will tend to depress the left wing. In the upper drawing, which shows the correct rotor-propeller combination, the rolling moment from the rotor acts in a direction opposite to the propeller torque, whereas in the lower drawing both the rotor rolling moment and the propeller torque reaction act in the same direction.

The difficulty of maintaining lateral balance that was experienced with Autogiros of the older type and the reduction of this difficulty in the newer machines has led to the following conclusion: In any satisfactory Autogiro, the rotor moments and the engine torque should be analyzed and the combination be arranged so that the rolling moments from these two elements will act to decrease the total final moment. Therefore, in a pusher, the directions of rotation of the propeller and the rotor should be opposite, when seen from the pilot's cockpit, whereas tractors have proved entirely satisfactory with the directions of rotation the same.

Balance Variation

To obtain data on the allowable displacement of the center of gravity that could be used in future designs, a number of tests have been conducted by the Autogiro Co. of America on Autogiros of various sizes. No attempt was made in the earlier tests to find the most nose-heavy condition that was regarded as allowable; the maximum tail-heavy condition alone being investigated. In the later tests, both the allowable nose-heavy and tail-heavy conditions were investigated.

The tests consisted in adding or deducting increments of ballast to or from the machine under test, in either the nose or the tail, depending upon the condition being investigated. A pilot would then fly the machine and,

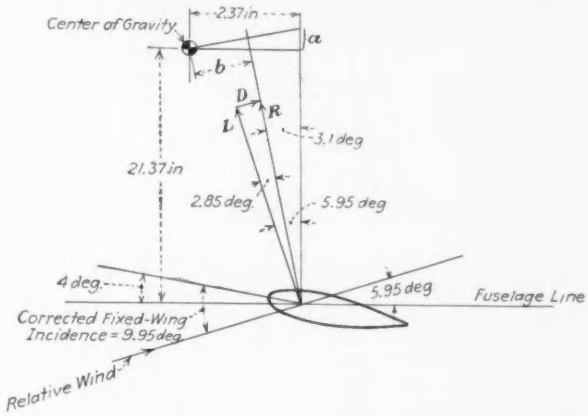


FIG. 17—DETERMINATION OF DIRECTION OF RESULTANT OF FIXED WING IN OBTAINING DATA ON ALLOWABLE CENTER-OF-GRAVITY DISPLACEMENT

The Angle the Resultant Wing Vector Makes with the Vertical Is

$$5.95 \text{ Deg.} - \text{Tan}^{-1} (1/20.1) = 5.95 - 2.85 = 3.1 \text{ Deg.}$$

Therefore

$$a = 2.37 \tan 3.1 \text{ Deg.} = 2.37 \times 0.0542 = 0.13 \text{ In.}$$

$$\text{Lever-Arm } b = (21.37 + 0.13) \sin 3.1 \text{ Deg.} - 0.13 \operatorname{cosec} 3.1 \text{ Deg.} = 21.50 \times 0.0541 - (0.13/0.0541) = 1.16 - 2.41 = -1.25$$

(These Reference Letters Apply to This Figure Only)

with throttle all the way back, determine whether he regarded the machine as being practical for a new pilot in case of loss of power. In the tail-heavy condition, the machine was considered satisfactory if, with the

TABLE 9—DERIVATION OF SECOND SET OF AUTOGIRO BALANCE FORMULAS

Machine	Gross Weight, Lb. W	Lift Carried by Wing, Per Cent	Lift Carried by Wing, Lb. L_w	Solidity σ	Fixed-Wing Incidence, Corrected (Fig. 18), Deg.	Center-of-Pressure Location, Per Cent of Chord	Aspect Ratio	L/D of Fixed Wing, Corrected (Fig. 19)	Incidence of Fixed Wing from Zero Lift Relative to Fuselage, Deg.	Fixed-Wing Lever-Arm[a], In.	Fixed-Wing Moment[b], Lb-In.	Correction to L_1[c] e	$L_1 + e_1$	h_1, In.	$(L_1 + e_1)/h_1$ f	d_1A_1	fW/d_1A_1 f_2	Deviation from Average, Per Cent
Tail-Heavy Balance																		
PCA-1 No. 3	2,394	3.6	86	0.0866	14.22	33.0	9.1	14.75	+4	7.36	634	—0.265	1.925	69.02	0.0278	6,900	0.0096	
C-19	1,302	3.6	47	0.106	14.3	26.0	7.7	12.40	+4	15.47	726	—0.558	1.507	48.95	0.0308	4,350	0.0092	
PCA-2 No. 5	2,497	3.6	90	0.0976	14.22	25.8	8.9	13.24	+4	5.61	505	—0.2	1.54	58.33	0.0264	6,310	0.0104	
PAA-1 No. 19	1,625	3.6	59	0.1003	14.27	25.9	9.43	13.60	+4	1.81	107	—0.066	1.164	52.29	0.0222	3,070	0.0117	
PAA-1 No. 19	1,600	3.6	58	0.1003	14.27	25.9	9.43	13.60	+4	2.53	147	—0.092	1.618	52.29	0.0309	3,070	0.0161	—7.5
PAA-1 No. 18, G-429 aft	1,437	3.6	52	0.1003	14.27	25.9	9.43	13.60	+4	—7.41	—386	+0.268	2.088	52.70	0.0396	3,020	0.0188	+8.0
PAA-1 No. 18, G-429 fore	1,630	3.6	59	0.1003	14.27	25.9	9.43	13.60	+4	1.41	83	—0.051	1.969	52.70	0.0374	3,025	0.0202	+16.0
PAA-1 No. 18, Camber fore	1,488	3.6	54	0.1003	8.77[d]	32.0	9.43	17.00	+4	1.93	104	—0.070	1.55	52.70	0.0294	3,020	0.0145	=16.7
																Average	0.0174[e]	
Nose-Heavy Balance																		
PCA-1 No. 3	2,831	7.0	198	0.0866	10.0	37	9.1	18.4	+4	1.72	340	—0.12	5.0	67.7	0.0739	6,780	0.0309	—2.9
PCA-2 No. 5	2,698	6.5	175	0.0976	9.96	24.2	8.9	20.2	+4	3.71	650	—0.24	4.38	60.6	0.0721	6,410	0.0303	—4.7
PAA-1 No. 19	1,500	5.5	82	0.1003	9.95	24.1	9.43	20.1	+4	—1.25[g]	102	0.068	3.45	53.2	0.0648	3,120	0.0312	—1.9
PAA-1 No. 18, G-429 aft	1,537	5.5	84	0.1003	9.95	24.2	9.43	20.1	+4	—9.07	—761	0.495	3.045	51.5	0.0591	3,040	0.0299	—6.0
PAA-1 No. 18, G-429 fore	1,494	5.5	82	0.1003	9.95	24.2	9.43	20.1	+4	1.37	112	—0.075	3.225	51.5	0.0626	3,060	0.0306	—3 9
PAA-1 No. 18, Camber fore	1.581	5.5	87	0.1003	4.45[f]	34.0	9.43	20.1	+4	2.13	—185	0.117	3.867	51.5	0.075	3,065	0.0387	+21.7[h]

[a] When the center of pressure of the wing is in front of the center of gravity, the quantity is positive.
[b] A moment tending to lower the tail is positive.
[c] A correction tending to lift the tail is positive.
[d] 14.27 — 5.5 = 8.77, as zero lift of Clark-Y is at —5.5-deg. incidence.
[e] Taken for last four tests.
[f] 9.95 — 5.5 = 4.45 deg., as zero lift of Clark-Y is at —5.5-deg. incidence.
[g] Sample computation attached as supplement to report.
[h] The factor derived from the final test does not agree very closely with others, as the effort of the wing has been approximated in assuming that Göttingen-429 with the drooped ailerons gave a Clark-Y section.

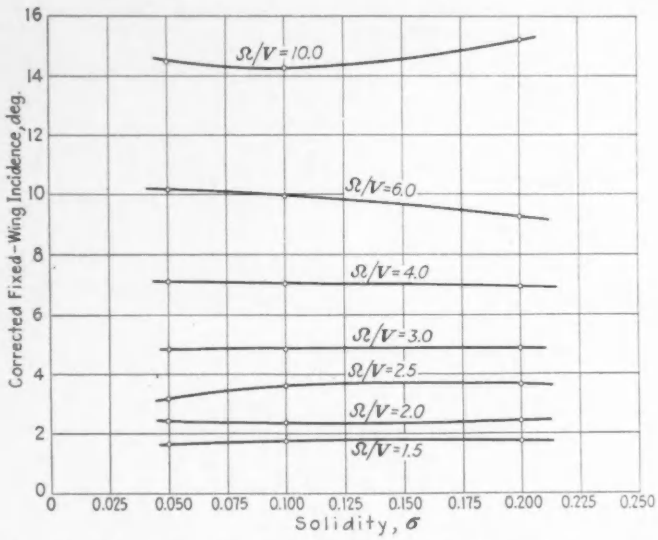


FIG. 18—CORRECTED FIXED-WING INCIDENCE PLOTTED AGAINST SOLIDITY

For Ratios of 1.5 : 10.0 of Rotor-Tip Speed to Displacement Speed When Pitch Angle of Blades Is 4 Deg.

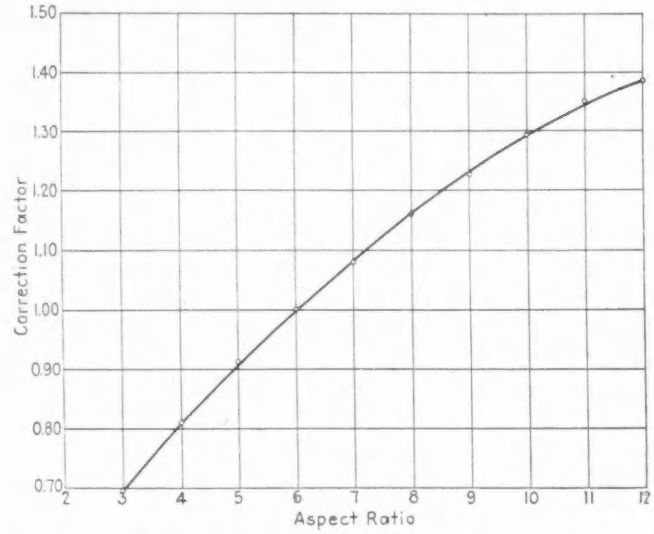


FIG. 19—LIFT-DRAG RATIO CORRECTED FOR ASPECT RATIO

For Test[6] in Which the Aspect Ratio Is 6

throttle all the way back, its tail would not drop and the machine would either make a tail slide or turn off to one side or the other, but would come down with a steady, slow, forward speed. In the nose-heavy condition, a machine was considered satisfactory if it could be landed "power off" with the Autogiro's normal characteristics.

Analysis of the data obtained from these tests indicates that three possible sets of empirical relations could be used in determining the allowable displacement of the center of gravity in future designs. In the first, the allowable movement is given simply in function of L_1/h_1, the gross weight of the machine and the tail moment. This will not be discussed further here. In the second method, the value of L_1 is corrected for the moment of the fixed wing (Fig. 17), and all characteristics, with the substitution of L_1 corrected for L_1, are used as in the first method. The third method consists in determining the moments given by the fixed wing and the rotor for the different locations of the center of gravity and different flight conditions and ascertaining the effectiveness of the tail moment in balancing the residual moment from the fixed wing and the rotor.

In the computations of rotor and wing moments from test data, the assumption has been made that the tests for the tail-heavy condition were made at $\Omega/V = 10$ and that those for the nose-heavy condition were made at

[6] See Simple Aerodynamics and the Airplane, by Charles N. Montieth, p. 60.

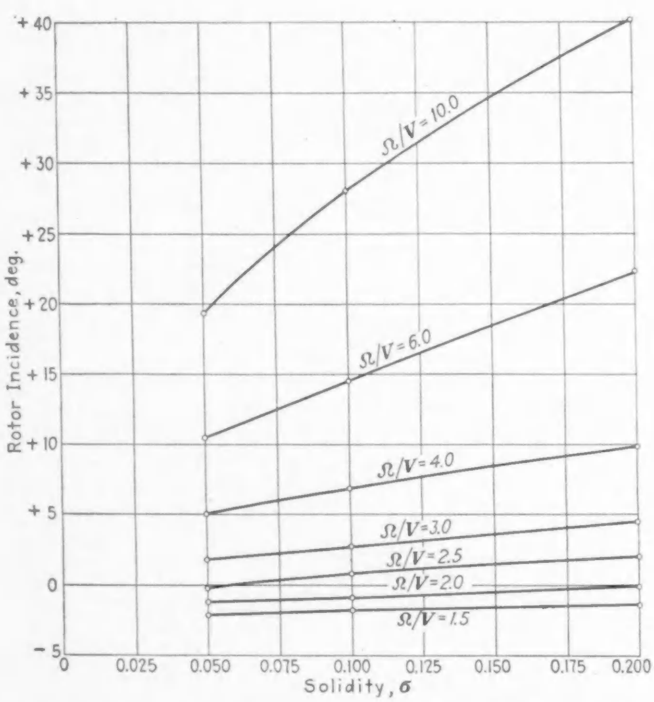


FIG. 20—ROTOR INCIDENCE PLOTTED AGAINST SOLIDITY WHEN PITCH ANGLE OF BLADES IS 4 DEG.

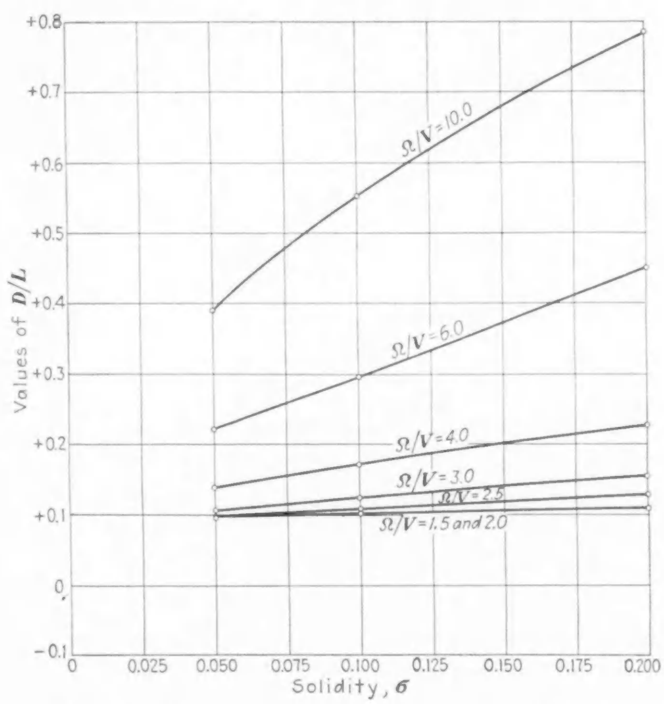


FIG. 21—VALVES OF D/L PLOTTED AGAINST SOLIDITY

$\Omega/V = 6$. The rotor characteristics for $\Omega/V = 6$ were obtained from the Theory; and the curves from the Theory were extended graphically to $V/\Omega = 0$ to extrapolate for $\Omega/V = 10$.

The steps taken in determining each set of the empirical relations for the allowable center-of-gravity location, with explanations of all computations that are not obvious, will be given in this study.

The first set of formulas was derived as functions of L_1/h_1, gross weight and tail moment. The gross weight used was the gross weight during any specific test. The tail moment was the distance between the center of gravity and the center of pressure of the horizontal tail surfaces, in inches, times the horizontal tail area in square feet.

In the second set of relations, the value of L_1 is corrected for the moment due to the lift of the fixed wing. All the machines tested have a fixed-wing area less than that for the "combination standard normal" (fixed-wing area = 100 per cent of virtual blade area), but all areas are such that they will carry nearly the same proportion of lift. By extrapolation, the fixed wings of all machines tested have been assumed to carrying 3.6 per cent of the gross weight of the machine at $\Omega/V = 10$ and computed for $\Omega/V = 6$ as outlined in the consideration of lift distribution between the fixed wing and the rotor. The direction of the resultant of the fixed wing is determined as follows:

Find the corrected fixed-wing incidence corresponding to the rotor solidity (Fig. 18), for which the airfoil characteristics (center of pressure and L/D) should be found. With these data, and knowing the set incidence of the wing with respect to the fuselage and the direction of relative air-flow across the wing, the distance between the center of gravity and the fixed-wing resultant can be determined either graphically or analytically. The fixed-wing moment is this distance times the lift carried by the fixed wing. This moment is converted to an equivalent gross center-of-gravity movement, and L_1 is corrected by this amount. This work is shown in Table 9.

This latter set of data seems to be a little more erratic for the tail-heavy condition, but more uniform for the

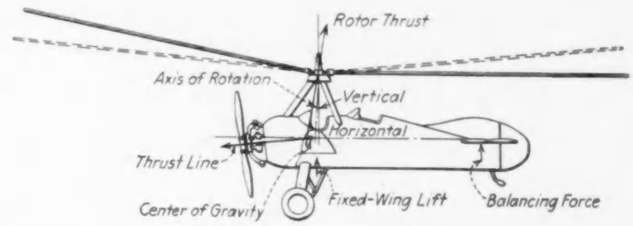


FIG. 22—SIDE VIEW OF AN AUTOGIRO INDICATING SOURCES OF LONGITUDINAL MOMENTS

nose-heavy condition, than the data worked out for the first case. However, as 5 lb. more or less of ballast in the tail of the PCA-2 will introduce a balance variation of approximately 1000 lb.-in., the data obtained are believed to be well within the experimental errors in tests of this nature, and an average of the nose-heavy and tail-heavy factors is believed to be a good criterion of the allowable center-of-gravity displacement in future designs.

Use of the second set of formulas is advised where the resultant from the fixed wing does not pass close to the center of gravity, as in the case of the C-19 Autogiro.

In the third method of analysis, the wing moments are determined exactly as in the second method. Length of the lever-arm of the rotor can be determined in the same way; that is, from a layout of the relative location and direction of the resultant rotor thrust and the center of gravity. For these low-speed conditions, the displacement of the rotor thrust line due to flapping is neglected, the resultant vector being considered as passing through the rotor center. The direction of the rotor thrust (referred to the constructional rotor axis) is determined by the rotor incidence (Fig. 20) and the rotor D/L ratio (Fig. 21). The angle that this resultant makes with the constructional axis is $\tan^{-1}(D/L)^{-i}$ and should always have a slope slightly ahead of the constructional axis.

In Table 10 the wing moments from Table 9 are

TABLE 10—DERIVATION OF THIRD SET OF AUTOGIRO BALANCE FORMULAS

Machine	Gross Weight, Lb.	Lift Carried by Rotor, Lb.	Solidity σ	i Rotor Incidence (Fig. 3), Deg.	Rotor D/L (Fig. 4)	α Constant Incidence of Rotor, Deg.	λ $\tan^{-1} D/L - i + \alpha$, Deg.	Rotor Lever-Arm $b - h_1 \tan\lambda$	Rotor Moment[a]	Wing Moment[a] (Table 2)	M Total Moment of Rotor Plus Wing[a]	M/d_tA_t Tail Load, Lb. per Sq. Ft.	Deviation from Average, Lb. per Sq. Ft.	Deviation from Average, Lb.
Tail-Heavy Balance														
PCA-1 No. 3	2,394	2,308	0.0866	29.6	0.584	1.42	2.12	—1.34	—3,100	634	—2,466	—0.358		
C-19	1,302	1,255	0.106	28.8	0.570	0.00	0.88	—1.31	—1,645	726	— 919	—0.211		
PCA-2 No. 5	2,497	2,407	0.0976	27.6	0.547	1.42	2.50	—0.63	—1,520	505	—1,015	—0.161		
PAA-1 No. 19	1,625	1,566	0.1003	28.1	0.560	1.67	2.82	—0.17	— 266	107	— 156	—0.051		
PAA-1 No. 19	1,600	1,542	0.1003	28.1	0.560	1.54	2.69	—0.65	—1,005	147	— 858	—0.279	+0.082	+1.81
PAA-1 No. 18 G-429 aft	1,437	1,385	0.1003	28.1	0.560	1.67	2.82	—0.75	—1,040	—386	—1,426	—0.472	—0.111	—2.44
PAA-1 No. 18 G-429 fore	1,630	1,571	0.1003	28.1	0.560	1.67	2.82	—0.95	—1,492	83	—1,409	—0.465	—0.104	—2.30
PAA-1 No. 18 Camber fore	1,488	1,434	0.1003	28.1	0.560	1.67	2.82	—0.55	— 790	104	— 686	—0.228	+0.133	+2.94
											Average,	—0.361[b]		
Nose-Heavy Balance														
PCA-1 No. 3	2,831	2,633	0.0866	15.30	0.314	1.42	3.55	—2.59	—6,810	340	—6,470	—0.956	—0.145	—6.10
PCA-2 No. 5	2,698	2,523	0.0976	14.3	0.292	1.42	3.40	—2.52	—6,360	650	—5,710	—0.890	—0.079	—2.78
PAA-1 No. 19	1,500	1,422	0.1003	14.5	0.296	1.67	3.65	—1.53	—2.180	—119	—2,299	—0.736	+0.075	+1.66
PAA-1 No. 18 G-429 aft	1,537	1,457	0.1003	14.5	0.296	1.67	3.65	—0.76	—1,107	—726	—1,833	—0.604	+0.207	+4.58
PAA-1 No. 18 G-429 fore	1,494	1,416	0.1003	14.5	0.296	1.67	3.65	—1.51	—2,140	107	—2,033	—0.665	+0.146	+3.23
PAA-1 No. 18 Camber fore	1,581	1,499	0.1003	14.5	0.296	1.67	3.65	—1.96	—2,940	—175	—3,115	—1.015	—0.204	—4.51
											Average,	—0.811		

[a] A moment tending to lower the tail is positive.
[b] Average of the last four previous items.

shown, together with a determination of rotor moments and total tail load in pounds.

Reference to Fig. 22 will clearly indicate the locations of the forces involved in this discussion.

For a preliminary design in which the fixed-wing resultant passes close to the center of gravity, an estimate of allowable center-of-gravity displacement, location of the center of gravity with respect to the centerline of rotation and the horizontal tail area required can readily be made, using the two relations

$$0.0173 = (L_1/h_1)_t \times \text{gross weight} \div \text{tail moment} \quad (6)$$
$$0.0313 = (L_1/h_1)_n \times \text{gross weight} \div \text{tail moment} \quad (7)$$

Where the fixed-wing resultant does not pass close to the center of gravity, the value of L_1 in Equations (6) and (7) should be corrected for the fixed-wing moment. When the corrections for fixed-wing lift are introduced, Equations (6) and (7) become

$$0.0174 = (L_{1c}/h_1)_t \times \text{gross weight} \div \text{tail moment} \quad (8)$$

and

$$0.0318 = (L_{1c}/h_1)_n \times \text{gross weight} \div \text{tail moment} \quad (9)$$

Either of the first two methods outlined in the foregoing will, it is believed, give satisfactory results for preliminary-design investigation. For the final choice of rotor, that is, for center-of-gravity location and tail-area required for a given center-of-gravity displacement, the sum of wing and rotor moments should be obtained as in the third method of procedure. For the extreme tail-heavy condition, the sum of the rotor and fixed-wing moments should be such as to require for equilibrium a down load of 0.361 lb. per sq. ft. or more on the horizontal tail surfaces, while the moments for the extreme nose-heavy condition should require a down load of 0.811 lb. per sq. ft. or less on the horizontal surfaces.

When the foregoing investigation was first undertaken, it was hoped to obtain data from more machines than were tested. However, the data from these tests seem fairly consistent, and the engineering division of the Autogiro Co. of America feels that the relations recommended will be a real aid to future designing.

Effect of Wings on Stability and Balance

Three combinations of wing location and wing section will now be analyzed as to their effect on longitudinal stability in flight and balance in descents approaching the vertical. Computations are put in tabular form and shown wherever this is deemed necessary. The measure of longitudinal stability is the amount of load required on the tail to balance the resultant of the wing and rotor moments. The permissible center-of-gravity displacement is computed using the factors previously set forth on safe balance of Autogiros.

Balance tests were run on a PAA-1 Autogiro to determine the maximum allowable nose-heavy and tail-heavy conditions, and the allowable center-of-gravity displacement was found to be 1.81 in.

The effect of shifting the wing aft 11 in. will now be noted. Assume that the wing has no effect in the tail-heavy condition. Therefore, being a constant-center-of-pressure wing, the aft location of the center of gravity relative to the pylon will not be changed. However, in the nose-heavy condition the allowable center-of-gravity location will move aft, as the wing tends to give an added pitching moment.

From our previous discussion it may be noted that the allowable nose-heavy-moment factor is 0.0316. Assuming this factor to remain constant, which is a logical assumption in view of all the flight tests, the new allowable limit for center-of-gravity location for this condition can readily be determined as follows:

TABLE 11—LONGITUDINAL-STABILITY DATA ON GÖTTINGEN-429 WING SECTION WITH FRONT SPAR 24 IN. AFT OF STATION 1[a]

Ω/V	Gross Weight, Lb.	Lift Carried by Wing, Per Cent	Lift Carried by Wing, Lb.	Fixed-Wing Incidence, Corrected, Deg.	Center-of-Pressure Location, Per Cent of Chord	$L/D \times 1.258$ (Correction to Aspect Ratio = 9.43)	Fixed-Wing Lever-Arm, In.	Fixed-Wing Moment, Lb-In.	Lift Carried by Rotor, Lb.	i, Rotor Incidence, Deg.	Rotor D/L	$\tan^{-1} D/L - i + 1.5$ Deg.	Rotor Lever-Arm, In.	Rotor Moment, Lb-In.	Total Moment, Lb-In.	Lever-Arm of Tail Surface, In.	Tail Load, Lb.
								Tail-Heavy Condition									
1.5	1,625	18.6	302	1.80	21.5	15.7	—1.75	—529	1,323	—1.75	0.100	8.97	8.15	10,800	10,271	138.8	74.0
2.0	1,625	13.9	226	2.35	21.8	19.8	—1.33	—301	1,399	—0.90	0.100	8.12	7.00	9,790	9,489	138.8	68.3
2.5	1,625	13.4	218	3.60	23.0	24.1	—1.01	—220	1,407	0.75	0.107	6.87	5.33	7,500	7,280	138.8	52.5
3.0	1,625	12.3	200	4.90	24.0	25.7	—0.76	—152	1,425	2.70	0.124	5.87	4.00	5,700	5,548	138.8	39.9
4.0	1,625	9.8	159	7.05	24.0	24.2	+0.03	+ 5	1,466	6.80	0.171	4.40	2.13	3,125	3,130	138.8	22.5
6.0	1,625	5.5	89	9.95	24.0	20.1	+0.98	+ 87	1,536	14.50	0.296	3.50	0.97	1,490	1,577	138.8	11.4
								Nose-Heavy Condition									
1.5	1,500	18.6	279	1.80	21.5	15.7	—3.81	—1,062	1,221	—1.75	0.100	8.97	5.97	7,300	6,238	141.0	44.2
2.0	1,500	13.9	208	2.35	21.8	19.8	—3.42	—712	1,292	—0.90	0.100	8.12	4.82	6,230	5,518	141.0	39.2
2.5	1,500	13.4	201	3.60	23.0	24.1	—3.14	—631	1,299	0.75	0.107	6.87	3.15	4,100	3,469	141.0	24.6
3.0	1,500	12.3	185	4.90	24.0	25.7	—2.91	—538	1,315	2.70	0.124	5.87	1.82	2,390	1,852	141.0	13.1
4.0	1,500	9.8	147	7.05	24.0	24.2	—2.16	—317	1,353	6.80	0.171	4.40	—0.05	—68	—385	141.0	—2.7
6.0	1,500	5.5	83	9.95	24.0	20.1	—1.25	—104	1,417	14.50	0.296	3.50	—1.21	—1,715	—1,819	141.0	—12.9

[a] Aspect Ratio = 9.43; $\sigma = 0.1003$; Wing Incidence = + 4 Deg. to Fuselage; Constructional Rotor Incidence = + 1½ Deg. to Fuselage (d).

Having moved the wing back 11 in., the new wing lever-arm is $-2 - 11 = -13$. The pitching moment due to the wing then becomes $13 \times 78 = 1014$ lb.-in., equivalent to a correction of $1014/1500 = +0.866$ in. to L_1, or

$$(L_{1c}/h_1)_n \times \text{gross weight} \div \text{tail moment} = 0.0316$$
$$L_{1c} = 0.0316 \times 141 \times 22.1 \times 53.19/1500 = 3.49 \text{ in.}$$

Therefore

$$L_{1c} + 0.866 = 3.49 \text{ in.}$$
$$L_{1c} = 3.49 - 0.87 = 2.62 \text{ in.}$$

However, L_{1c} was = 3.38 in. for the normal PAA-1, so that the allowable limit of the center of gravity would be moved aft a distance = 3.38 − 2.62 = 0.76 in. by the 11-in. movement of the fixed wing.

The effect of replacing the original wing in its forward position by a wing having a Clark-Y section will now be noted.

The center-of-pressure location of a Clark-Y airfoil in high angle of attack is 34 per cent, as compared with 24.2 per cent for the Göttingen 429. Therefore, the wing vector in this condition will be $0.098 \times 30 = 2.94$ in. farther aft than in the same condition with the Göttingen 429.

TABLE 12—LONGITUDINAL STABILITY DATA ON GÖTTINGEN-429 WING SECTION WITH FRONT SPAR 35 IN. AFT OF STATION 1

Ω/V	Lift Carried by Wing, Lb.	Wing Lever-Arm, In. F-19	Wing Lever-Arm, In. F-18	Moment Due to Wing, Lb-In.	Lift Carried by Rotor, Lb.	F-19 Rotor Lever-Arm, In.	Moment Due to Rotor, Lb-In.	Total Moment, Lb-In.	Lever Arm of Tail Surface, In.	Tail Load, Lb.
					Tail-Heavy Condition					
1.5	302	—1.75	—12.65	—3,825	1,323	8.15	10,800	+6,975	138.8	50.2
2.0	226	—1.33	—12.27	—2,770	1,399	7.00	9,790	+7,020	138.8	50.6
2.5	218	—1.01	—11.99	—2,615	1,407	5.33	7,500	+4,885	138.8	35.2
3.0	200	—0.76	—11.74	—2,350	1,425	4.00	5,700	+3,350	138.8	24.1
4.0	159	+0.03	—10.97	—1,744	1,466	2.13	3,125	+1,381	138.8	10.0
6.0	89	+0.98	—9.99	— 881	1,536	0.97	1,490	+ 609	138.8	4.4
					Nose-Heavy Condition					
1.5	279	—3.81	—14.69	—4,090	1,221	5.97	7,300	+3,210	141.0	22.7
2.0	208	—3.42	—14.36	—2,985	1,292	4.82	6,230	+3,245	141.0	23.0
2.5	201	—3.14	—14.12	—2,835	1,299	3.15	4,100	+1,265	141.0	9.0
3.0	185	—2.91	—13.89	—2,565	1,315	1.82	2,390	— 175	141.0	— 1.2
4.0	147	—2.16	—13.16	—1,932	1,353	—0.05	— 68	—2,000	141.0	—14.2
6.0	83	—1.25	—12.22	—1,014	1,417	—1.21	—1,715	—2,719	141.0	—19.3

Therefore, the new wing lever-arm is $-2 - 2.94 = -4.94$ in. Pitching moment $= 4.94 \times 78 = 385$ lb.-in., equivalent to a correction to L_{1c} of $385/1500 = +0.26$ in. Therefore

$$L_{1c} - 0.26 = 3.49 \text{ in.}$$
$$L_{1c} = 3.49 - 0.26 = 3.23 \text{ in.}$$

Therefore the limit of center of gravity should be moved aft $3.38 - 3.23 = 0.15$ in. Therefore the reduction in allowable center-of-gravity displacement required for the Clark-Y section is less than for the 11-in. change in location of the Göttingen 429 wing.

From a study of the last column of Table 11 it may be noticed that in the high-speed condition a large amount of up-stabilizer is required to maintain the Autogiro on an even keel. Then, comparing with Table 12, it may be noted that a smaller amount of up-stabilizer is required and a little more down-stabilizer. However, the range required of the stabilizer has been reduced to $(50.6 + 19.3)/(74 + 12.9) = 69.9/86.9 = 80.5$ per cent of that in Table 11.

A further comparison with Table 13 shows the required amount of stabilizer movement to be $(44.7 + 14.7)/86.9 = 59.4/86.9 = 68.5$ per cent of that in Table 11 and $50.4/69.9 = 85$ per cent of that in Table 12.

Considering these three combinations with particular reference to balance in descent conditions, it may be noted that the first combination is the best, as it allows the greatest displacement of the center of the gravity. The second combination, although it gives an improvement in longitudinal stability, as shown by the less up-stabilizer required, curtails the allowable center-of-gravity movement by 0.76 in., or a reduction of $0.76/1.81 = 42$ per cent.

The third combination, showing a still greater improvement in longitudinal stability, curtails the allowable center-of-gravity movement by only 0.15 in., or a reduction of $0.15/1.81 = 8.3$ per cent. Therefore, this last combination is by all means preferable.

Flight tests were then run on another Autogiro with the wing in forward position, ailerons drooped and incidence decreased so that the wing would have the same effect upon the rotor that it has on the normal PAA-1. The standard model was flown first and proved to be unstable, in that at a cruising speed of 85 m.p.h. it "hunted" rather badly. The modified Autogiro was flown with satisfactory results as to stability characteristics. At the same cruising speed it showed a considerable improvement in stability over the standard model. The two ships were tested extensively and demonstrated the improvement of stability when a cambered wing having a large center-of-pressure travel replaced the symmetrical section. A further flight test of balance conditions showed a large improvement in allowable center-of-gravity displacement over the symmetrical section.

Conclusions

The data given in this paper indicate some of the tremendous amount of detail development that has been devoted to the aerodynamic and structural relationships of the modern Autogiro. Many additional researches are being carried on: One of the licensees is demonstrating corrective measures toward higher efficiency by washing in the outer portions of the fixed wings with low aspect ratio; the N.A.C.A. is preparing for flight-check tests on its Autogiro, in which the fixed wings are fitted with manometer tubes to study the distribution of pressure; and other studies have to do with the longitudinal and lateral lift and thrust vectors of the rotor.

TABLE 13—STABILITY DATA ON CLARK-Y WING SECTION WITH 25 PER CENT OF CHORD 24 IN. AFT OF STATION 1

Ω/V	Fixed-Wing Incidence Corrected from Zero Lift, Deg.	Fixed-Wing Incidence Corrected, Deg.[a]	Center-of-Pressure Location, Per Cent of Chord	$L/D \times 1.258$	Wing Lift, Lb.	Wing Lever-Arm, In.	Wing Moment, Lb-In.	Rotor Moment, Lb-In.	Total Moment, Lb-In.	Lever Arm of Tail Surface, In.	Tail Load, Lb.
					Tail-Heavy Condition						
1.5	1.80	—3.70	75	10.0	302	—19.06	—5,760	10,800	+5,040	138.8	36.3
2.0	2.35	—3.15	67	12.1	226	—15.88	—3,585	9,790	+6,205	138.8	44.7
2.5	3.60	—1.90	52	17.7	218	—10.07	—2,198	7,500	+5,302	138.8	38.3
3.0	4.90	—0.60	44	21.4	201	— 7.30	—1,467	5,700	+4,233	138.8	30.5
4.0	7.05	1.55	39	23.2	159	— 4.51	— 717	3,125	+2,408	138.8	17.3
6.0	9.95	4.45	34	20.9	89	— 2.10	— 187	1,490	+1,303	138.8	9.4
					Nose-Heavy Condition						
1.5	1.80	—3.70	75	10.0	279	—21.24	—5,930	7,300	+1,370	141.0	9.7
2.0	2.35	—3.15	67	12.1	208	—18.06	—3,760	6,230	+2,470	141.0	17.5
2.5	3.60	—1.90	52	17.7	201	—12.25	—2,460	4,100	+1,640	141.0	11.63
3.0	4.90	—0.60	44	21.4	185	— 9.48	—1,753	2,390	+ 637	141.0	4.5
4.0	7.05	·1.55	39	23.2	147	— 6.69	— 982	— 68	—1,050	141.0	—7.5
6.0	9.95	4.45	34	20.9	83	— 4.28	— 355	—1,715	—2,070	141.0	—14.7

[a] Zero lift of Clark-Y section at 5.5 deg. lower than Göttingen 429 section.

The Relationship between Automobile Construction and Accidents

By Maxwell N. Halsey[1]

Annual Meeting Paper

DISPARITY between the factors of automobile and highway design that are far advanced and the factors that lag far behind constitutes the cause of many of our transportation difficulties, according to the author. The paper therefore aims to show the demand for safety and its economic advantage to the automotive industry and to indicate some of the principles necessary for its accomplishment.

After stating that the automobile manufacturers should take a far-sighted view of the situation, take positive steps toward safety and cash in on the demand that is growing and that cannot be stopped by denying its existence, the author considers and comments upon some of the characteristics of automobiles that undoubtedly are partly responsible for accident potentialities. Visibility from the driver's seat is considered in detail, together with devices that assist visibility. The other driver's viewpoint also is considered.

Aids to steering safety are outlined, braking-system improvements are indicated and means for avoidance of distracting drivers' attention from their duties are enumerated. Air pollution inside the car is discussed and means for minimizing it are suggested. Fire-hazard factors are considered, as well as the subject of reducing damage caused by accidents.

In the discussion, means for simplifying the control of an automobile are advocated, the suggestion is made that need may arise to install on cars larger and more adequate brakes than those now in use, the importance of good visibility is emphasized and steering mechanisms are criticized.

PROGRESS in any field of endeavor can be made only if time, energy and money are concentrated on those items that lag farthest behind and need the most attention. At present, some factors of automobile and highway design are far ahead; others, far behind. This disparity causes many of our transportation difficulties. For instance, the present speed capability of cars is far in excess of the ability of roadways to accommodate it or of present-day drivers to handle it with safety. In addition, the potential speed of cars today is far ahead of their inherent safety, when the limitations of human nature and human ability are considered. A detailed recital of accident statistics is unnecessary to show the unbalanced condition existing in automobile transportation. The mere facts that more than 35,000 persons were killed and 1,000,000 injured in 1931 and that $900,000,000 worth of damage was done, due to accidents, constitute a sufficient index to show where concentration on improvement is needed. If this paper can show the demand for safety and its economic advantage to the automotive industry and can indicate some of the principles necessary for its accomplishment, it will have served its purpose.

Some improvements foster new hazards. While the manufacturer has not recognized safety demands generally, he has acknowledged certain specfic ones and has made improvements to meet them. Unfortunately, while some of these improvements reduced one particular hazard, they fostered changes in driving characteristics—such as higher speeds—and thus brought about new and different hazards. Better brakes, improved head-lamps, a lower center of gravity and the higher comfortable economic speeds of even the lower-priced cars have provided more of a temptation than human nature can withstand, and driving speeds have increased. This increase in the average speed has thrown an additional burden upon the manufacturer and has tended to magnify greatly the importance of safety construction. Hence, for every improvement that permits greater mobility, the manufacturer must increase still further the safety devices of the motor-vehicle. In fact, the improvement of safety devices must be greater than the increase in speed or the former will not offset the latter. As speed increases, additional braking distance for each mile per hour is necessary because the demolition or impact factor increases at a greater rate than does the speed, and because the reaction time, and probably the general ability of the individual motorist, remains about the same.

Safety Activities Aid Business

Many safety activities exist in which the industry should join because they are a business aid to it. Motor-vehicle inspection campaigns and laws furnish a good example of this. Initially, the industry may have felt that the annoyance of these inspections would reduce sales. It may have overlooked their effect on one of its greatest problems, that of used cars. Rigid inspection several times a year, as is now being done in several States, should remove thousands of unsafe used cars from the highway and thus make room for more replacements. Since but 28 per cent of the expenditure is for new cars and 72 per cent or $8,574,000,000 for repairs, parts, supplies, labor and accessories, the dealer should be vitally interested. Such safety movements mean a definite financial gain to the manufacturers and to the dealers. A reduction in accidents and congestion cannot help but make the automobile more attractive as a personal unit of transportation and will prevent its potential users from adopting other forms of transportation. Therefore the automobile manufacturers should take a far-sighted view of the situation, take positive steps toward safety and cash in on the demand that is growing and that cannot be stopped by denying its existence.

Under present accident-reporting systems by cities and States, getting accurate and complete records of automobile accidents and their specific causes is exceedingly difficult for several reasons. For instance, laws requiring reporting are different, jurisdictions overlap,

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reports are received from State and city officials and motorists and, frequently, the record systems do not include sufficient detail. An accident often has more than one cause, and to allocate the correct percentage to each contributing factor is difficult. Hence, determining exactly what percentage of accidents is caused by equipment that is defective either in design or because of poor maintenance is impossible at present.

Of the 46,047 accidents reported in Pennsylvania for November, 1931, 8 per cent apparently were caused by some mechanical failure. These are classified as follows, in percentage: Defective brakes, 31; steering gears, 16; tire punctures, 14; glaring head-lamps, 11; smooth tires and no chains, 10; no tail-light burning, 9; and no head-lamp shown on the vehicle, 9. They totaled 368 and resulted in the death of 12 persons, the injury of 327 and the demolition of property valued at $52,700. Hence the National total for a year must be considerable.

While building up National figures on the basis of one State is not entirely feasible, still the results will show a situation that is just as likely to be right as wrong. Extended to include the entire Country, on the foregoing basis 95,000 accidents would be due to mechanical defects, which would kill over 3000 people, injure 85,500, and cause over $13,000,000 worth of damage. This is an obvious reason why automobile insurance rates are high and will be higher. These sample figures show the potential picture.

Making the Vehicle Safe

Let us now consider some of the characteristics of automobiles that undoubtedly are partly responsible for the foregoing accident potentialities and indicate some of the possible methods of improvement.

At the present rate of accidents involving injuries, the manufacturer should expect that each car he sells will eventually be involved in one or more accidents. Since the human element is admitted to be the greatest factor in automobile accidents, he should improve those things that reinforce the abilities of drivers and overcome their deficiencies. As motor-vehicle inspections, improved by the use of permanent inspection stations and more frequent inspections, have frequently shown that as many as 50 per cent of the brakes and 66 per cent of the head-lamps were out of adjustment, the manufacturer should endeavor to make his vehicles as easy to maintain and as automatic in adjustment as possible.

Visibility from the Driver's Seat

The exact position of the driver's eyes in the car must be used as a basis for determining his ability to see. That the driver can look around obstructions after moving his head is not sufficient, for, although he can move his head, one may be very sure that he will not. He will drive right on until some object comes into his existing field of vision.

The tendency to have motorists sit lower in the car frequently means that the level of the driver's eyes is almost as low as that of the cowl. The result is that he cannot see the fender or any low object within 10 ft. of the car. This condition probably can be improved by lowering the cowl and lowering the steering-wheel so that the driver can see over it or reducing the size of the wheel rim and the number and size of the spokes. Another horizontal obstruction, particularly for tall drivers, is the sun visor. This difficulty has been lessened recently by moving the visor inside the car and making it adjustable.

The pillars supporting the windshield form a vertical obstruction that can be minimized considerably. A decrease of 1/4 in. in pillar width, when the pillar is close to the driver's eye, will decrease in width by several feet the blind spot 50 ft. ahead. Top supports are almost in the same category, although visibility behind the front seats is not needed so frequently as in front, and probably more structural difficulties are involved. This condition can be improved definitely by adding more footage of glass back of the driver's seat.

Clear windshields are necessary. The method of mounting probably is responsible for the many cracked windshields, which soon collect dirt. Windshield wipers have been improved. When two are used, fair visibility results in bad weather; however, a possibility of devising a simple mechanism that will clean a greater area still remains. Snow, sleet and ice removers, the effectiveness of which can be counted upon, have yet to be devised. The quantity of heat needed to do the work in spite of the difference of temperature inside and out, and its effective application, make the problem very difficult.

One of the most serious interferences with vision is the refraction of light from outside sources through the windshield, side and rear glasses. This has been successfully dealt with in front by slanting the windshield. The side and rear windows eventually will need to receive the same treatment. The dash lights still offer some light interference even in the best-designd instrument-boards. It is suggested that the use of "position-reading" instruments with only the arrow and numbers illuminated may be of some assistance in reducing glare. That many of the instruments can remain dark until the pointer indicates that a danger point has been reached is also not beyond the realm of possibility. Thus, eventually, such instruments as the engine-heat indicator, the ammeter and the gasoline and oil gages may be made to light up automatically when the pointer reaches the indication at which the driver's attention is needed. But the speedometer should be constantly and adequately illuminated at night so that it can be read quickly and easily.

Assistants to Visibility

Head-lamps that provide adequate side lighting and a long beam that does not glare are of great importance at night. The side lighting has been effectively improved in some cars, but the "distance throw" without glare has not been produced. Some light beams have a sharp "cut-off," but even these are subject to glare because of bumps in the road or because of poor adjustment. The assembly should be made such that the head-lamps cannot get out of adjustment to the extent of throwing the beam above the horizontal. Another possibility is that the head-lamp units can be mounted in such a way as to compensate automatically for bumps in the road or heavy loads in the back seat. The vertical location of the lamps may come in for some intensive study, because the heads of drivers, on account of low seating, are closer to the surface of the road. It is doubtful that drivers will add to their driving habits that of dimming their head-lamps for each approaching vehicle. Driving a car for long distances requires a sufficient number of manipulations as it is, and approaching cars are too frequent. In very low-hung cars, in which the driver has difficulty in seeing the fenders, indicators have been developed to show him just where the outside of his car is. These sometimes serve a second function of indicating the outline of his car to approaching motorists.

Rear-vision mirrors still leave blind spots behind the car. Located at the center, the mirror is adequate for a straight view behind, if it is in line horizontally with the rear window and if none of the passengers obstructs the view. Even then, however, it will not indicate the overtaking vehicle that is about to pass on one side or

the other. The fender or door-hinge mirror is of some assistance for this purpose, but, with the increased width of rear seats and rear ends, even it is becoming ineffective. Possibly a compound mirror will be developed for closed cars. Craning of the driver's neck is exceedingly unpopular; in fact, it is seldom done and he goes blindly ahead and not infrequently becomes involved in an accident.

The Other Driver's Viewpoint Considered

Let us now consider visibility from outside the vehicle:

Head-lamps.—The head-lamp must serve several functions in addition to illuminating the road. It should indicate the outline of the car for the benefit of approaching motorists. Its present tendency to glare and its location prevent it from doing this at present. It also should provide side illumination so that the vehicle can be seen by cars approaching from the side. Here again it fails at present.

Side Lights.—Fender lights serve to outline the car and provide side illumination, but the same result might be obtained by a redesign or relocation of the head-lamps and tail-lamp.

Rear Lights.—The rear light has been assigned numerous jobs, chief among which is to inform motorists approaching from the rear of the car's presence. Greater illumination is needed than now exists, because motorists do not clean the lenses frequently enough. Side and license-plate illumination also needs improvement.

Reflecting Lamps.—A type of reflecting glass has been developed which is now being used to replace the tail-lamp and cowl-lamp lenses in many cars. When the lamp is lighted, adequate light is thrown out. When the filament burns out, the glass provides adequate illumination by reflecting the light from approaching head-lamps up to a distance of 100 to 200 ft. This glass affords automatic protection in case of tail-lamp failures and is now required on all cars registered in Colorado. Several other States require it on the rear of trucks and motorcoaches. This is the sort of automatic protection with which the industry should provide the motorist. That he will be too lazy or forgetful to check his lamps frequently enough should be assumed.

Telltales.—Since the motorist neglects to check his lamps, providing him with telltales so that he will at least know, without having to get out of his car, which lamps are burning and which are out might be advisable. Some head-lamps have been provided with pencils of glass or apertures to show when they are burning. At one time on some cars the tail and dash-lamps were in series to show whether they were both in working order. I have resorted to a 21-cp. stop-light so that, by watching the needle in the ammeter, I can tell whether the stop-light is in working order.

Parking Lights.—One reason that motorists hesitate to leave a lamp lighted on their parked car is because on many cars the wiring is such that, to keep the tail-lamp illuminated, two cowl lights and two dash lights must be lighted. These five lights represent a considerable drain on the battery. Either the wiring should be changed or an additional switch or lamp provided.

Headlighting versus Highway Lighting.—There has been considerable agitation recently regarding highway lighting; but obviously its cost will restrict it to the metropolitan areas and the more important trunk lines. Elsewhere it probably will prove more economical to light the highway only when cars are actually using it. Thus it is evident that there is a definite demand for improved head-lamps with more light on the road, better side lighting, and a considerable reduction of glare.

Aids to Steering Safety

The driver's compartment should be designed so as to assist him in his steering operations and not to interefere with them. If it is assumed that maximum steering efficiency can be obtained if the driver is directly behind the steering-wheel, then that position should be made comfortable for him. The widening of the front seat to admit three persons has tended to force the driver to the left of the steering-wheel if he is to have an arm rest and desires to lean against the side. Making the side of the compartment adjustable, as well as the back of the seat, might be possible. Many drivers have had trouble because of insufficient clearance around the outside of the wheel from the windshield, cowl, door, gearshift lever and the individual himself; at high speeds, the hazard of having the driver's hand or elbow jammed, even momentarily, is obvious.

Other serious interferences with steering are projections that catch the driver's sleeve when he is about to make a turn. There appears to be no logical or economical reason why the window and door handles cannot be designed and located so as to make this impossible, without interfering in the least with opening and shutting the door or window. Light, gas and spark levers mounted on the steering-post are also sources of interference. The light levers are probably the worst offenders because, at night, they are not only likely to catch the sleeve and interfere with steering, but at that crucial moment they may also turn out the lights. Further, they provide a dangerous place into which one of the driver's thumbs or fingers can become wedged. Why not use countersunk levers or switches?

Braking-System Improvements

The location of brake levers is a problem that still needs attention. The brake pedal needs a guard so that the driver's foot will not slip off of it in an emergency. As in most cases the pedal is located near the steering-post, this might be used as a foot-guide to the pedal. As the steering-post tends to slant more and more toward the driver, the brake and the clutch pedals might be made to slide down it in grooves, thus providing a straight-line push, if this should prove advantageous and the necessary linkage would not offset the advantage.

The relationship between the location of the brake pedal and that of the accelerator might be given further study to prevent accidents caused by the driver's foot slipping from the brake to the accelerator pedal. A raised edge on the brake-pedal—collapsible if necessary—might be of some assistance. The location of the hand brake has always caused difficulty. First, the driver has to reach too far and too low to get a quick grip on it; second, when it is part way back it is in an awkward position to pull on and the driver's hand tends to slip off of it. If three persons are in the front seat, to take hold of present emergency-brake levers is hard, if not impossible. If the emergency brake is to be used only in case of the failure of the conventional foot-brake system, why not provide an additional emergency-brake pedal that could be reached much more easily? If necessary, it could be operated by the left foot, would automatically throw out the clutch and could be made to lock down for a parking brake. It could be located so that it would not be in the way nor be confused with the clutch pedal. Another alternative would be a hand brake more nearly shoulder high, where it could be reached when three are in the front and permit a much stronger pull. I am aware of the difficulties involved in

the use of cables or multiple levers, yet much can be done to improve the location of the various pedals and levers.

Avoidance of Distracting the Driver

The more simple the operation of a car is, the less attention the driver needs to give to it and the more he can give to watching the road. Free-wheeling undoubtedly has reduced the energy and the number of movements necessary to shift gears, and the more these can be reduced the safer the operation will be. Apparently, the aim is to limit them to a simple motion, which is desirable. For the same reason increasing the braking power on free-wheel cars so that the same stopping distance can be had as before free-wheeling was installed is necessary; otherwise, the driver is forced to go through the motions of changing into conventional gear to be able to stop as quickly as he formerly could.

Higher speeds have necessitated improvements so that instruments can be read more quickly. If difficult to read, the driver will not attempt to read them or will be so slow in doing so that he may be involved in an accident before he can again watch the road. On some cars, many drivers take nearly 3 sec. to read the speedometer; in some cases it is hidden by the steering-wheel or is over in the center and low down on the instrument-board. At 60 m.p.h. a car travels 264 ft. in 3 sec. Accuracy of the speedometer is particularly important with modern cars, because the engines are so quiet and the roads so smooth that a driver has difficulty in estimating whether a car is traveling 30, 40 or 50 m.p.h.

Design and location are the two factors that mainly affect the reading of instruments. The design of instruments is important and should be such as to provide the quickest and most accurate reading possible. The "position-reading" arrow or needle type has a distinct advantage. Reading numbers is difficult, particularly when they are moving or being shaken by the action of the car; but with the position-reading type that is not necessary, because the driver soon learns their location and simply notices the relative position or angle of the pointer. On almost all instrument dials the number of numbers might well be lessened. Few drivers are interested in knowing whether the car is traveling 20 or 22 m.p.h. and 5-mile or 10-mile dial markings would be sufficient and would simplify the reading. Some study might profitably be made to determine the colors and contrasts to be used for the numbers, the pointer and the background, particularly considering lighting and night operation. That black and white give the greatest contrast seems reasonable, and the pointer and the numbers should receive the illumination, not the background, since an illuminated background tends to interfere with the driver's operation.

As to location, the nearer the instrument is to the driver, the closer it is in line with his line of vision to the highway and the more quickly he can read it. Hence all instruments that need to be read or moved while the car is in motion should be located as nearly as possible directly in front of the driver and as high as possible without interfering with his vision. His sight is then diverted from the roadway only for the minimum time. The speedometer should be centered vertically with the steering-post, and it might possibly be placed above instead of below the windshield if that would bring it closer, horizontally, to the driver's eyes. Since drivers presumably will continue to wear hats, some space still remains between the top of the windshield and the top of the car. This space, which is closer, horizontally, to the driver's eyes than the instrument-board, could be used advantageously for instruments.

Some instruments are of greater importance as regards safety than others. At high speeds the speedometer is of greatest importance, yet it has not received preferential treatment. In some cars the two largest instruments are the clock and the speedometer, both located equidistant from the center of the car; in others, the clock is nearest the driver, though, in still others, the speedometer is given the better location. To locate the speedometer nearest the driver seems more simple, economical and safe. The appearance of the instrument panel has influenced the past design and location of instruments; but, with the number of instruments increasing, locating the vital instruments in front of the driver and installing the new and less important ones at the right would be advantageous.

An instrument may have only a single point of interest to the driver, who is not so much interested in the degree to which the condition is right or wrong; all he wants to know is whether the generator is charging, the oil pressure is adequate and the engine is too hot. To have the "wrong" condition indicated automatically by a red light seems reasonable. This would reduce by 50 per cent the number of instruments to be read and would be a surer method of indicating to the driver that something was wrong. If this were done, the speedometer might be the only instrument continuously illuminated at night, since a separate switch easily could be provided for the gasoline gage and the clock. Adopting some standard for instruments so that their positions, and colors, if any, would have standard meanings seems advisable. This would be particularly true of speedometers, which might be designed so that the bottom of the dial reads 0 and 100, the top 50, the left 25, and the right 75 m.p.h.

Air Pollution Inside the Car

Fresh air of suitable temperature and degree of humidity must be provided for the occupants of cars. Polluted air makes driving unpleasant and tends to dull one's senses. The more nearly air-tight the body is, the more satisfactorily the problem can be dealt with. Leaks into the car are usually through the front floor-boards or the cracks surrounding the doors. Improvement in construction of the part of the body nearest the engine is most important because it is here that the gases from the engine, as well as those sucked up from other cars, are blown in to the passengers. Opening the windshield not only causes considerable draft but small stones, bugs and bees may blow in and are likely to interfere with driving, particularly with the use of the eyes.

The development of ventilation is still not far advanced. In cold weather, that all the ventilation must be through the windows should not necessarily be assumed. If air is taken in from the front, it causes strong drafts. The experiments of the Pullman Co. led to the conclusion that the air should be sucked out of a railroad-car body and be permitted to leak in through the numerous small gaps, leaving the windows almost entirely out of consideration. Why would it not be feasible to adopt this practice? The heating of a car has been considerably improved, yet many of the systems bring engine fumes and odors into the car, a good part probably being due to leaks in the flexible tubing.

The real source of obnoxious gas and odors probably is an unsuitable fuel mixture fed to the engine by the carbureter. This is caused by faulty carbureter adjustment and is particularly true of motorcoaches, which usually exhaust such odorous fumes that motorists hate to drive behind them and frequently take considerable risk to pass them. Some time ago progress was reported on a device that would adjust the carbureter according to the condition of the exhaust gas. If the problem were attacked from this end, fuel economy and fresh air might be achieved at the same time.

Leaky mufflers are another source of air pollution. If the use of the "straight-through" type increases, this difficulty probably will be greatly lessened. A further improvement might be to move the muffler toward the rear of the car, or to provide a draft or ventilation toward the rear for it. Using the blast from the exhaust to suck the air out of the car body might be possible, unless such a process would tend to develop back pressure. Some combination with the fan and the draft through the radiator might also be utilized.

Driving Comfort an Important Factor

Comfort has a part in preventing accidents, its most important influence being the lessening of bodily and mental fatigue. Longer trips than formerly are now taken customarily by motorists and, undoubtedly, many accidents are caused by fatigue and a consequent lengthening of drivers' reaction time. Many cars do not provide sufficient room for the driver to change his driving position. This inability to stretch his muscles gives him a feeling of being cramped and tends to make him nervous. The adjustable front seat has improved the situation somewhat; but not altogether, because, for each driver, the front seat has one position that places him in the best position to reach the steering-wheel and control levers. If in this position he does not have sufficient room to stretch his legs, he is not comfortable. Window sills seem to tend to become higher, particularly in relation to the driver's seat, which increases the difficulty for him to rest his left arm. This indicates a demand for an arm rest.

Front seats are being made wider to accommodate three persons. With the steering-wheel located at the center of the left half of the front compartment, the driver does not sit directly behind the wheel. Even with only two in the seat, he is tempted to sit close to the left side to find an arm rest. Thus he is more nearly behind the left windshield pillar and his driving ability is lessened. Therefore locating the steering-wheel directly in front of where the driver will sit if there are three in the front seat, and making the windshield just as wide as the front seat seems advisable. The angle of the steering-wheel to the driver might also be advantageously studied from the viewpoints of safety and comfort.

In many cases the pedals are not placed at the correct angle and the driver's foot soon becomes cramped. In some cars the accelerator is too far to the right, particularly when three are in the front seat. The whole instrument assembly can be vastly improved from the viewpoint of comfort to the operator. Low brake pedals, made more possible by power brakes, will be an improvement and will reduce the time needed to apply the brakes. With the advent of free-wheeling and power brakes, complete revision of the location of the clutch, brake and accelerator levers is likely. Before this comes, a comprehensive study should be made and a standard location determined.

Fire-Hazard Factors

Although the fire hazard of the automobile has been greatly reduced, many fires still occur in which motorists are burned to death. Safe design and location of the gasoline tank undoubtedly are important. The desirability of its location in front is rather doubtful, because of its proximity to the carbureter and its pipe lines and to the ignition. Its location in the extreme rear may have some drawbacks because of rear-end collisions and the danger of its being punctured by sharp objects that may cause explosions due to sparks. If possible, it should be located in such a position as to be protected by the body and the frame.

Pipe lines probably constitute the greatest fire hazard. They are more subject to breakage than is the gasoline tank, and some of them are closer to the hot parts of the engine and to the ignition system. To give them the physical protection of the frame and the engine wherever possible, instead of merely running them unsupported across large air gaps, seems advisable. Special precautions must be taken when lines are carried from one part of the car to another part that may bend slightly under road shock. The entire layout should be based upon the assumption that at some time during the car's life it will be involved in a serious crash.

Ignition systems have been improved greatly and short-circuits are far less frequent than formerly; however, much remains that can be done to design them so that failures will not result in sparks and fires or explosions. The wiring layout should avoid as much as possible the gasoline tank, the pipe lines, the carbureter and any surface where gasoline leakage or a crash might provide the combination necessary for an explosion or fire.

Reducing Damage Caused by Collision

The latest figures indicate that, in all accidents involving personal injury, 45 per cent of the casualties were caused by broken glass. The greater part of this injury can be reduced by using non-shatterable glass, a type that has been made available throughout in some of the higher-priced cars, is stock equipment in the windshields of others and can be provided in most cars at an extra charge. Recently one manufacturer has provided this feature in all windows of his cars in his four price classes. The Michigan law will require it in all public conveyances in 1933 and in all vehicles by 1934. Since the trend and the law will require it, the problem resolves itself into developing a product that will not discolor and will resist breaking.

The body should be strong enough to afford the passengers some degree of protection; it should not serve merely as a unit to hold the top up and the windows in place. Its greatest weaknesses lie in the doors and the top. The doors probably could be designed so that, in case of collision, they could draw from the vertical and top members for support. The top is probably the most vulnerable part of the body. In many cases it simply will not stand up under the strain of having the car turned over. Although the vertical supports may be of sufficient strength, the joints are not of equal strength, particularly when subjected to a twisting action. The whole body should be of equal comparative strength, and any one part should receive support from every other part.

The deceleration of the modern car is greater than will permit the passengers to keep their seats in an emergency, and the impact of an accident is sufficient to throw them with considerable force. Therefore the inside of the body should be as free from sharp projections as possible. The instrument-panel and cowl layout can be made less irregular. Hard-rubber steering-wheels probably would prevent the rim from breaking and puncturing the driver. The top bows might be located so that passengers will not hit them when thrown up by bumps or collisions. Provision should be made to prevent the hood hinge-rod from being pushed back to the front seat and through some passenger. In airplane design rather common practice is to build in "crash-pads," although the accidents per unit of operation are supposed to be less than those for motor-vehicles.

The safety catch on doors has without doubt reduced the number of injuries caused by doors opening and letting passengers fall out, although cases still occur when the body of the car is twisted or is struck suddenly. The design of some doors is such that, in case of an accident in which the body is struck, they cannot

be opened and the passengers are kept inside to drown or burn.

Property damage could be reduced considerably by providing side bumpers or designing the running-boards to serve as bumpers.

Conclusions

The number and severity of accidents still increase, owing largely to driving speeds that are higher than can be handled safely on existing roadways by present drivers. This condition undoubtedly will continue until the advance of the various factors involved has been adjusted and until organization, personnel and public attitude have been developed sufficiently to offset it. Safety is very much in the public mind today. Motorists have been informed of the seriousness of the condition. Thousands of people are actively engaged in safety work, so that the theory and practice of safety will become even better known. The industry must meet this demand for sales purposes. That the building of safe automobiles and the active participation of the industry in safety campaigns is a business aid and that much good-will and profit will result therefrom are equally evident.

In the majority of the safety problems, as they affect the construction of the vehicle, the automotive industry already knows the answer. In regard to brakes, the opinion of a number of automotive engineers who are in a position to know what they are talking about is that probably not more than three stock cars are manufactured today which have brakes adequate to make three emergency stops from a speed of 60 m.p.h. without having the braking system robbed of its effectiveness; yet not a private car is manufactured today that will not do 60 or 70 m.p.h. and that is not frequently used at that speed. Common sense should dictate that, if a car is built which can travel 60 m.p.h., brakes should be provided that will stop it from 60 m.p.h. in emergencies, not only three times but often enough so that frequent maintenance, which the motorists will not give to a braking system, is not necessary.

THE DISCUSSION

P. J. KENT[2]:—Simplifying the control of an automobile is a very distinct trend at present. In driving a car we really do only two things; one is to control the speed and the other the direction. Therefore, two controls should be sufficient. The new car models indicate that progress is being made in the elimination of some of the control operation.

Direction signals and their application have been discussed for years; perhaps, eventually, everybody must have a direction signal. If the direction signal is mounted on the pillar post so that the driver can see it operate, he is likely to use it. To design a head-lamp mounting that would prevent adjustment of head-lamp beams above the horizontal would not be simple. The difference between a properly adjusted and a badly adjusted head-lamp is only a degree or two, and the dimensions of fenders, tie-rods and head-lamp mounting brackets vary considerably, so that control of head-lamp adjustment is not so easy. The only way it could be done successfully from a production viewpoint would be to have two adjustments; one whereby the head-lamp would be adjusted and locked at the factory so that the beam could not be adjusted above the horizontal, the other being one that would be left free for adjustment from the horizontal position downward. Even then, variations in filaments, socket location and things of that kind will change the adjustment. Thinking of the headlighting problem from the viewpoint of glare alone is not sufficient. It must be considered also from the viewpoint of illumination because having the beams pointed down so far that the driver cannot see a sufficient distance ahead is just as unsafe as to have them pointed up.

MAXWELL HALSEY:—I have tried out different types of direction signal. The main trouble lies with the design of certain cars. For example, my car is narrower at the front than at the rear; so much so that a direction arrow cannot be seen by a driver within about 50 ft. behind me because it is hidden by the rear of the body. If the arrow projected any farther, it would be out beyond the front fender. Much study is needed before a practicable solution is reached.

Lock-nuts, cotter keys and other devices designed to keep car units together are in use, but mechanics sometimes fail to replace them after repairs are made. Perhaps a simpler method may be evolved so that such complete reliance upon the human element is not necessary.

T. J. LITLE, JR.[3]:—A number of safety precautions can be taken by automobile builders, and road builders and municipal authorities also could adopt a number. We may need to install larger and more adequate brakes than the ones now in use. A large number of mechanical brakes on the better cars are adequate, but a large number on the cheaper cars are inadequate. I think that brake drums of larger diameter and brake bands that are wider will be installed on most motor-vehicles in the coming year, particularly on free-wheeling cars. We would better use brakes that are larger than necessary than to use inadequate ones.

LYLE K. SNELL[4]:—A heavy vehicle can be stopped as quickly as a light one if it has satisfactory brakes on all four wheels. Good visibility is the most important factor in automobiles so far as safety is concerned. I think that money is wasted by our municipalities on highway lighting; the illumination should be on the automobile.

E. B. NEIL[5]:—With the advent of balloon tires the entire steering mechanism of the automobile was revised. Since then, steering-gear reduction ratios have been increased, and present ratios of say 20 or 22 to 1 are not uncommon. Comparing the new vehicles with those of 15 years ago, including racing cars, the steering-gear reduction ratio has been increased so that less control over the vehicle exists today than at that time. Has the relationship between reaction time and the time required to turn the front wheels one way or the other in an emergency been considered?

Are we not going fundamentally wrong in not thinking more about the steering linkage in connection with its speed of action? For instance, perhaps three full turns of the steering-wheel may be needed to cramp the front wheels from one side to the other with the present type of linkage. This is a serious reflection on the controlability of the vehicle. I know from racing experience that one could not successfully drive the ordinary type of road vehicle on a race track and feel entirely safe, because a driver must be able to turn the front wheels say 15 or 20 deg. without removing his hands from the steering-wheel; that is, by turning the wheel say a quarter turn or a half turn. At present, to turn a corner, the driver must give the wheel a turn and a half or two turns; whereas, with the old type of steering-gear, he could round a corner without removing his hands from the wheel. Providing much greater control over the vehicle is possible when the front wheels can be turned rapidly from one side to the other, which cannot be done with the present type of steering-gear. To decrease the ratio seems advisable, using some auxiliary steering mechanism if necessary.

[2] M.S.A.E.—Chief electrical engineer, Chrysler Corp., Detroit.
[3] M.S.A.E.—Engineer and industrialist, Detroit.
[4] M.S.A.E.—Consulting engineer, Detroit.
[5] M.S.A.E.—Engineering adviser, N. W. Ayer & Son, Philadelphia.

The Properties and Selection of Automotive Steels

Chicago Section Paper

By Thomas H. Wickenden[1]

METALLURGISTS must supply engineers with data on the physical properties of steels so that the skill of both can be used, particularly for machinery in which light weight is essential. The engineer who has not a metallurgical department at his command cannot be sure of duplicating results claimed by steel makers, and the physical-property data that have been given in the S.A.E. HANDBOOK are based on minimum results, for safety.

More complete information as to what actually can be expected is desirable, and a subcommittee has had a large number of tests made on identical samples from several heats of two alloy steels. The results for these two steels have been coordinated in probability curves that were developed with the aid of frequency charts.

Some steels are not uniform in their physical properties in large sections. The author presents suggestions for steels that are suitable for large sections, with the strengths that can be expected from them. Gear steels are treated in a brief analysis, and European practice is cited for gear steels and automobile construction in general, including a table of recommendations made by a British standardizing body.

BOTH THE ENGINEER and the metallurgist must contribute their highest skill in the design and manufacture of machinery in which minimum weight is essential; in this field the two professions are drawn together most closely and must intermingle on a common ground for the best results and full appreciation of each other's problems. The engineer must be partly metallurgist and the metallurgist must be partly engineer to meet the mutual problems.

Machinery in which weight saving is a minor consideration may operate successfully if it is crude in design; the size of parts can be such that the localized stresses produced by undercuts and sharp changes in section and keyways in full-size shafts may be disregarded almost with impunity. The properties of the materials may vary over a wide range and still the machinery will operate with satisfactory life.

How different is the story when minimum weight is essential. Stresses must be analyzed, generous fillets must be used and undercuts and threads on highly stressed parts must be avoided. Splines on enlarged sections of a shaft supersede keyways, and even rough finish and scratches must be avoided. The material must respond readily to heat-treatment, and deep-hardening properties must be considered to assure uniform properties throughout the piece and in every piece. Materials capable of resisting high stress and great impact and with better wearing properties must be introduced. The necessary rigidity of the part must me maintained by clever design, as the metallurgist has not yet learned the secret of greatly modifying the modulus of elasticity of steel.

Metallurgist Relied upon for Data

As the basis for this work, the metallurgist must supply the engineer with reliable data on steels and other materials so that the parts can be designed for suitable stresses. Some large firms have a sufficient laboratory staff to determine their own information, but by far the majority are dependent upon data from outside sources, such as that contained in the S.A.E. HANDBOOK. Some physical-property curves published by steel companies are the results of tests on a single heat of steel that was picked for its exceptional properties. The engineer cannot safely use this information as a working basis; he is not so much interested in exceptional properties as in properties on which he can rely.

The S.A.E. data sheets have been criticised because they do not show the highest values of which the various steels are capable; in other words, because the curves are over-conservative. This is true necessarily, and that very fact should be considered as a recommendation and promote confidence in their use by the engineer. The values shown in the present S.A.E. curves were determined by dividing the steels tested into two groups according to their carbon contents. The ultimate strengths and yield points were taken from materials having their carbon contents in the lower half of the range, the elongation and reduction of area were taken from steels with carbon values in the upper half of the range, and the Brinell hardness numbers were taken in the middle of the section of the heat-treated specimens. This method results in curves approximating the minimum values; they are conservative and safe for the engineer to use as a basis of computation.

Causes of Variation in Properties

Making a representative physical-property chart for an S.A.E. steel is not as simple as might appear from the finished charts. There are a number of variables which disturb an otherwise smooth curve. The variables which affect the uniform values are : (*a*) variation in chemical analyses within the chemical-specification range, (*b*) variation in properties of different heats of steel of the same chemical analysis, and (*c*) variations from the specified heat-treatment, due to the personal equation. These will be discussed in the order named.

Chemical Analysis.—Anyone who is familiar with the chemical and physical changes occurring during the melting process and the casting of a heat of steel will appreciate the difficulties of a steel maker in meeting the chemical specification in a 100-ton heat of open-hearth steel or in a 15-ton heat of electric-furnace product. Those who have attempted to meet chemical specifications in smaller batches in crucibles or small electric or high-frequency furnaces without the complication of refining are probably amazed that the commercial

[1] M.S.A.E.—Assistant manager of development and research, International Nickel Co., New York City.

steel maker can hold the composition as closely as he does.

Carbon, which is one of the most effective elements in developing strength in steel, is permitted to vary over a 10-point range. A narrower range is practicable only in special cases and justly demands an extra from the steel companies. The ranges of the alloying elements all play an important part, and the variations permitted are as follows: manganese, 30 points; nickel, 50 points; chromium, 30 to 50 points; molybdenum, 10 points; and, vanadium, minimum specified, desired given, no upper limit. Two extremes in composition are possible, both within the chemical specification, which show considerably different physical characteristics. While these extreme combinations are rare, it is a condition which must be recognized in presenting data in the form of a physical-property chart. To present data on steels with all the elements at the minimum would not be fair or represent commercial conditions.

Variation between Different Heats.—Steels of the same chemical composition can have different physical properties. This is a subject on which we are gradually accumulating more data. The McQuaid-Ehn tests brought the variables of grain size or rate of grain growth into the open. The steel companies have learned many of the controlling factors in regulating grain-size characteristics so that they are willing to accept specifications calling for material to be within a certain grain-size range. Many metallurgists have found this desirable, on steels used in important parts, to bring out uniformity in heat-treatment and resulting physical properties.

A steel possessing inherent tendencies toward a rapid grain growth shows considerably different physical properties than a steel of the same general analysis but having slow grain-growth characteristics.

Certain alloying elements, such as chromium and manganese, increase the tendency of a steel to show rapid grain growth, while the addition of nickel retards the action. The natural grain-growth characteristic of a steel can be altered by making small additions of vanadium, aluminum and possibly other elements to a molten heat at the proper time.

The usual method of determining the grain-growth characteristic is the McQuaid-Ehn test, which consists of carburizing a sample of steel at 1700 deg. fahr. for 8 hr. and cooling in the box. A cross-section of the sample is polished for microscopic examination, and the grain size produced is rated by checking against an empirical standard chart. When a steel is heated through the critical point, it recrystallizes, and the grain size shown in the final piece is an indication of its grain-growth characteristics. This test is a method of bringing out these characteristics.

H. J. French, in studying some manganese molybdenum steels, noted widely different properties in different heats of this steel of about the same analysis[2]. Study of the grain-growth characteristics of these steels indicates that the mechanical properties varied over a wide range with the grain-growth classification. Fig. 1 shows that the strength of the hardened steels increased and the ductility and notch-toughness decreased with increase in the grain size, and that these differences were as large as those produced by appreciable variations in the manganese content. A striking example is furnished by the Izod values of the hardened cores of $2\frac{1}{2}$-per-cent manganese-molybdenum steel, as indicated in the lower part of Fig. 1. The energy absorbed was about 80 ft.-lb. in the fine-grained steel and only 17 ft.-lb. in the coarse-grained steel.

Fine-grained steels are to be preferred as to toughness, but carburization difficulties may be encountered unless adequate control of the grain size is maintained. For example, an exceedingly shallow case was obtained in the very fine-grained manganese-molybdenum steel.

Other influences, such as the gas content of a steel, are being studied; and another variable that we now known very little about may possibly be controlled as this information develops.

Variation from Heat-Treatment.—Variations in heat-treatment are bound to occur, even in the best-regulated plants. These variations are well illustrated in the cooperative tests run by the S.A.E. Subcommittee on Physical-Property Charts on S.A.E. Steels 6130 and 3130. Samples from four heats of steel, each secured from a different steel company, were sent out to 28 cooperating testing laboratories with uniform instructions covering quenching and drawing temperatures. Among the cooperating laboratories were 8 steel labora-

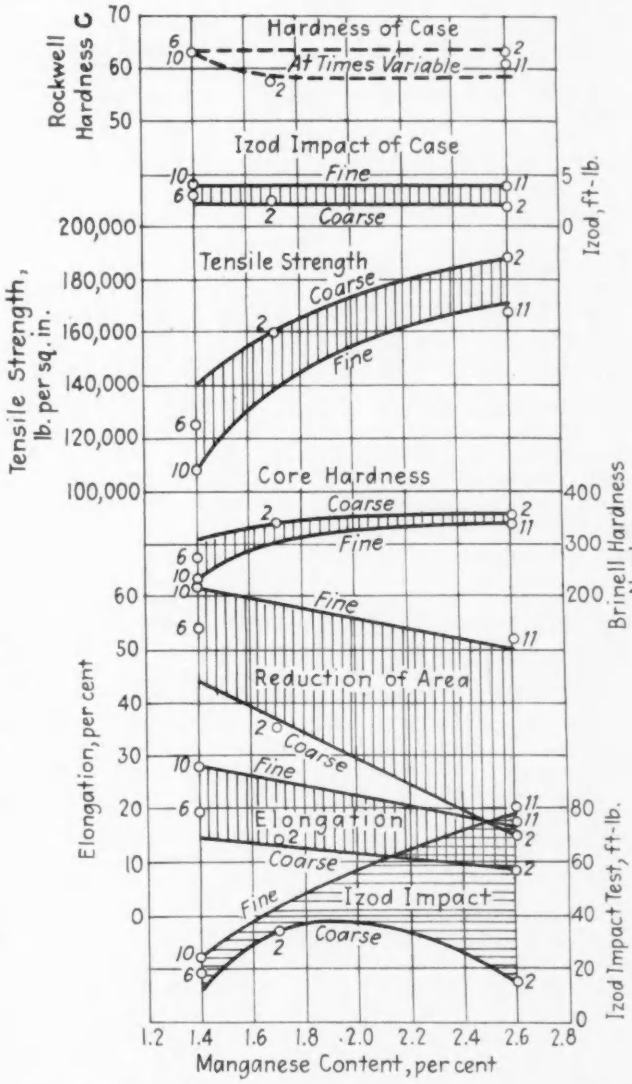

FIG. 1—MECHANICAL PROPERTIES OF MANGANESE-MOLYBDENUM STEELS

Properties Are Charted against the Manganese Content, Variation Resulting from Change in Grain Size Being Indicated by Shaded Areas. Numbers Opposite Plotted Points Indicate the Approximate Grain Size by Ehn Tests. Core Properties Are Shown in the Lower Part of the Chart and Properties of the Hardened Case at the Top. The Carbon Content of the Steels Was 0.14 to 0.18 and the Molybdenum Content 0.15 to 0.30 Per Cent. The Quenching Temperatures Were 1550 Deg. Fahr. for the 1.4 to 1.7-Per Cent Manganese and 1475 Deg. for the Higher Percentages of Manganese

[2] See The Quenching of Steels, by H. J. French; American Society for Steel Treating, Cleveland, 1932.

tories, 14 automotive laboratories, 4 research laboratories, 1 Government and 1 consulting laboratory. All of these laboratories are well equipped and have technical personnel of a high order, but the variations reported from these different sources are surprising and emphasize a personal equation which must be dealt with. It would require a bold technical jury to decide which results are right and which are wrong.

The following shows the difference between maximum and minimum tensile strength on each heat of one chromium-vanadium and one nickel-chromium steel, tempered at 800 deg. fahr.

S.A.E.-6130, Heat	Difference in Ultimate Tensile Strength, Lb. per Sq. In.	Difference in Brinell Hardness Number
A	42,100	104
B	20,425	15
C	29,800	22
D	43,550	90
S.A.E. 3130, Heat		
A	23,000	40
B	17,500	47
C	18,700	48
D	13,000	44

The bars for each mill heat were from a single billet, so the composition actually varied over only a narrow range. However, the variation in analyses reported for each heat varied over an appreciable range, showing the possibility of variation from another human equation.

The variation in physical properties from a single heat is due to variations in heat-treatment, in accuracy of pyrometers and in position of the couple in relation to the test piece. Variation in quenching temperature above the critical point of these alloy steels in a 1-in. bar has only a mild effect on the physical properties; the main cause for difference is variation in the drawing temperature.

One point that this test emphasizes is the futility of specifying drawing temperatures on a blueprint. A better system to avoid these variations and assure uniform properties in the finished piece is to specify Brinell or other hardness limits on the heat-treated or finished piece. The Brinell hardness number of a steel is closely related to its ultimate tensile strength, so the desired strength is sure to be there when the hardness requirements are met. Shallow-hardening steels are an exception. Carbon steels are noted for their shallow-hardening properties; if they are heat-treated in sections more than 1 in. through, a marked difference in hardness will be found between the outside and the center, and the surface hardness is not a true index of the strength of the body of the piece.

Tests reported on four mill heats of S.A.E.-6130 chromium-vanadium steel, heated to 1600 deg. fahr., and S.A.E. 3130 chromium-nickel steel, heated to 1525 deg., both quenched in cool water and tempered for 1 hr. at 800 deg. fahr., showed variation in results as indicated in Table 1.

Method of Presenting Data

Considering this variation, what is the best method of charting physical-property data? The S.A.E. Committee thought that showing minimum values would not give the correct picture and that a single curve showing average values might be misleading, but that showing a range, limited by probable maximum and minimum values, would give a true and clear picture of the situation. The use of actual maximum and minimum values from all tests might mislead by including freak values from improperly conducted tests. The method decided upon was to construct frequency or probability curves, such as are much used in other sciences when dealing with variable data. The simple graphical method for averaging individual curves that was used in the development of the frequency curves, together with actual curves of S.A.E.-6130 steel, were presented by E. T. Janitzky[3]. Curves for S.A.E.-3130 and 6130 steels, developed in this way, have been recommended[4] for inclusion as general information in the S.A.E. HANDBOOK.

Selection of Steels

The design of an airplane, automobile, truck or tractor is closely interwoven with the materials used. The engineer should know the working stresses that he wishes to use and the metallurgist the steel which will best meet the stress, fatigue, shock and resistance to wear and present the minimum fabricating and heat-treating difficulty in the shop. The metallurgist should work with the engineering department in the early stages of design, to avoid physical requirements which are extremely difficult to meet in the shop. Thin walls, deep undercuts or sharp corners may cost constant care in the hardening room to avoid warpage or cracking.

Carbon steel will always find a wide use in machine parts where moderate strength and toughness are satisfactory. Parts of small section can easily be hardened by quenching in water, but high-carbon steel and a drastic quench are required to secure strengths of more than 100,000 lb. per sq. in. in parts of 2-in. section. This causes danger of cracking unless the part is of uniform section. Alloy steel and oil quenching are advisable for parts having considerable variation in section. If the shop is limited to water quenching, a low-carbon alloy steel can be used; for example, if water-quenched S.A.E.-1045 steel is necessary in carbon steel to get the strength, water-quenched S.A.E.-3130 may be substituted. S.A.E.-3135, quenched in oil, will give the same strength without danger of cracking, and the resulting piece will be much tougher. This is illustrated in the tests reported in Table 2. Considerably higher yield point and Izod impact are secured with the alloy steels. Table 3 contains suggestions to guide in the

[3] See S.A.E. JOURNAL, January, 1928, p. 55.

[4] See S.A.E. JOURNAL, January, 1932, Section 3, p. 11, and February, 1932, p. 26.

TABLE 1—DISTRIBUTION OF RESULTS IN TENSILE TESTS

Ultimate Tensile Strength, Lb. per Sq. In.	Number of Tests within Range S.A.E. 6130	S.A.E. 3130
145,000-155,000	2	0
155,000-165,000	10	18
165,000-175,000	20	56
175,000-185,000	37	36
185,000-195,000	10	4
205,000-215,000	2	0
Total Spread, lb. per sq. in.	56,700	31,500

TABLE 2—DATA ON CARBON AND ALLOY STEELS IN 2-IN. ROUNDS

S.A.E. Steels	1045	3130	3135
Quenching Temperature, deg. fahr.	1600	1525	1550
Drawing Temperature, deg. fahr.	900	1000	1000
Drawn in	Water	Water	Oil
Yield Point, lb. per sq. in.	77,000	97,500	90,600
Ultimate Strength, lb. per sq. in.	116,000	120,000	118,000
Elongation, per cent	22	21	22
Reduction of Area, per cent	56	62	60
Brinell Hardness No.	235	243	231
Izod Test, ft-lb.	15	75	70

selection of steels for heavy sections. In it are shown the Brinell hardness number, the corresponding strength of the steel and the quenching medium for sections of different diameters.

The nickel-chromium-molybdenum steel referred to in Table 3 is gaining considerable favor for use in heavy parts, such as rear-axle driveshafts of trucks and motorcoaches. Typical properties on bars heat-treated in 3-in. sections by quenching in oil from 1525 deg. fahr. and tempering at 900 to 950 deg. are: Brinell hardness number, 415; tensile strength, 190,000 lb. per sq. in.; yield point, 165,000 lb. per sq. in.; elongation, 12.5 per cent; reduction of area, 50 per cent; and Izod impact test, 27 ft-lb.

Gear Steels

No discussion of automotive steels would be complete without reference to those used for gears. Gear steels occupy a field of their own, and it would be impossible to include more than a meager discussion of them in a paper of this type.

There will always be considerable difference of opinion regarding the relative merits of oil-hardened and case-hardened gears. The former have lower cost to recommend them, while the latter have greater toughness and resistance to wear. The value of nickel in increasing the toughness and decreasing the sensitiveness to variations in quenching temperature is brought out in Table 4. Study of this table shows that

(1) The effect produced on the toughness by increasing the nickel content is quite evident.
(2) The effect of overheating for quenching is very much lessened with increasing nickel content.
(3) Full hardness is developed at low quenching temperatures with the nickel steels.

The Lewis formula for figuring the strength of gear teeth is not suitable for determining the size and permissible load of automotive gears, as the strength of the tooth is not so much a consideration as is the capacity of the tooth to resist wear. When the unit pressures on the tooth are sufficiently low to avoid pitting of the face and rapid wear, the gears generally are sufficiently strong to avoid tooth breakage if they are made of an inherently tough steel. Gears of case-hardened steels, because of the high carbon content, strength, and hardness of their tooth surfaces, permit the use of greater unit loads than do oil-hardened gears.

The unit pressure at the point of contact between two gear teeth can be determined by the Hertz formula, but the question of the stress allowable for satisfactory life remains.

TABLE 3—ANALYSES OF STEEL FOR DIFFERENT STRENGTHS IN VARIOUS SECTIONS[a]

Brinell Hardness Number.	Tensile Strength in Mid-Section, Lb. per Sq. In.	Diameter of Section, In.				
		1	2	3	4	5
187-212	90,000-100,000	1035*w* 3130*ow*	1045*w* 2340*o*	3140*o* 2340*o*	3140*o* 2340*o*	3140*o* 2340*o*
212-248	100,000-115,000	1040*w* 3130*ow* 2330*ow*	1045*w* 3130*w* 3135*ow*	3140*o* 2340*o*	3140*w* 2340*w*	3145*w* 3240*o*
248-285	115,000-130,000	3130*w* 2335*o*	3140*o* 2340*o*	3145*w* 3240*o*	3145*w* 3240*o*	3240*o* NCM*o*
285-321	130,000-150,000	3130*w* 3140*o*	3145*o* 2345*o*	3240*o* 3435*o* 33.40*o*	3340*o* NCM[b]*o*	3340*o* NCM[b]*o*
321-363	150,000-170,000	3140*o*	3240*o* 3435*o*	3340*o* NCM[b]*o*	3340*o* NCM[b]*o*	
363-401	170,000-190,000	3435*o* 3240*o*	3340*o* NCM[b]*o*	3340*o* NCM[b]*o*		

[a] Analyses are given in S.A.E. Specification numbers, except for one special steel. *w* indicates quenched in water, *o* indicates quenched in oil, and either quenching medium can be used where both letters are shown.

[b] Nickel-chromium-molybdenum steel of the following analysis in per cent: carbon, 0.35-0.40; chromium, 0.60-0.80; nickel, 175-2.00; molybdenum, 0.30-0.40.

TABLE 4—EFFECT OF NICKEL ON IMPACT PROPERTIES OF GEAR STEELS

S.A.E. No.	Composition, Per Cent C	Ni	Cr	Quenching Temperature, Deg. Fahr.[c]	Izod Impact, Ft-Lb.	Brinell Hardness Number
5153	0.47	...	0.90	1475 1600	5.5- 6.0 3.0- 4.0	444-534 514-534
3245	0.52	1.67	1.00	1425 1600	10.5-12.5 3.5- 8.0	514-540 514-540
3445	0.50	2.75	0.94	1425 1600	14.0-14.5 13.0-13.0	514 514-555
2345	0.46	3.38	...	1425 1600	14.0-16.5 15.5-18.0	514-555 514-578

[c] All specimens quenched in oil and tempered at 400 deg. fahr.

I am of the opinion that pitting of a gear tooth is a surface-fatigue failure due to repeated compressive stressing above the compressive endurance limit of the steel. If this is true, the allowable stress is a function of the endurance limit on repeated stressing from zero to the maximum. Most available data on endurance limits are on either alternate tension and compressive stressing or stressing under tension alone, so the assumption has to be made that the endurance limit under compression follows the same general laws and is of the same order of values. Available data indicate this to be true.

An oil-hardened gear-steel of S.A.E.-2350 or 3250 analysis will have a Shore hardness of about 72 or a Rockwell hardness of C-52. This corresponds to a tensile strength of about 270,000 lb. per sq. in. and an endurance limit under alternate stress of about 115,000 lb. per sq. in. As the stress at the tooth contact is in one direction only, the endurance limits under this condition would be about 50 per cent greater, or 173,000 lb. per sq. in. Allowing a factor of safety on this maximum figure will give a suitable designing stress. The maximum unit surface stress for passenger-car-transmission service with intermittent use would be of the order of 160,000 to 165,000; for trucks, 150,000, and somewhat lower for continuous service.

On case-hardened gears, hardness values of between 80 and 85 Shore are common, which correspond to surface strengths of 315,000 to 320,000 lb. per sq. in. Fatigue tests by J. C. A. Woodbine[6] on carburized specimens with the core removed showed endurance limits on the case of 134,000 lb. per sq. in. for S.A.E.-2315 and 143,000 for S.A.E.-2512 steel. The endurance limit on the case-hardened surface under compressive stress from zero to maximum would be of the order of 200,000 lb. per sq. in. for S.A.E.-2315 and 215,000 for S.A.E.-2512 steel.

These values have been used for automobile transmissions for intermittent service, with figures on maximum engine torque, but a suitable factor of safety should be applied for a truck or tractor or for constant service. In checking these values I have been informed by the metallurgist of a truck company that case-hardened 5-per-cent-nickel-steel transmission gears have given satisfactory wear when the unit load on the tooth contact, figured from maximum engine torque, did not exceed 225,000 lb. per sq. in. At a unit stress of 240,000 lb. per sq. in., the gears pitted rapidly. The actual loads, of course, were intermittent and would not reach these values, as no allowance was made for friction losses.

Foreign Automotive Steels

In checking over the specifications of foreign cars, one is impressed by the lack of unified steel specifications such as we have in the S.A.E. HANDBOOK. An ef-

TABLE 5—BRITISH RECOMMENDATIONS FOR STEELS FOR AUTOMOBILES, PROPOSED FOR STANDARDIZATION

B.E.S.A. Specifications.	Description	Carbon	Silicon	Manganese	Sulphur	Phosphorus	Nickel	Chromium	Vanadium	Molybdenum	Tungsten	Yield Point Tons □″	Max Stress Tons □″		Elongation %	Reduction of Area %	Izod ft. lbs.	Brinell Hardness	Condition	Use.
			Max		Max	Max			Max	Max	Max	Min	Min	Max	Min	Min	Min			
3.S. 15	3% Nickel Case hardening steel	.10 to .15	.30	.20 to .60	.05	.05	2.75 to 3.5	Max .30					45	60	18	45	40		Refine 860°C. W.Q. 770°C.	Valve rocker spindles, Oil pump housing gear, Magneto driving gear-Tappets.
D.T.D. 3	5% Nickel Case-hardening steel	.10 to .15	.30	Max .40	.04	.04	4.75 to 5.5	Max .30					70	85	15	40	30		O.Q. 830°C. W.Q. 750°C.	Gudgeon Pins, Crown Wheels, Bevel pinions, Eccentric Impeller gears.
S.69	3½% Nickel Steel	.35 to .45	.30	.50 to .80	.05	.05	3.25 to 3.75	Max .30					55	65	18	50	35	241 to 293	O.Q. 830°C. and T. 530–630°C.	Cam shaft gear, Propeller Hub Crankcase bolts, Clutch bolts.
3. S. 11	55 ton Nickel-Chrome Steel	.25 to .35	.30	.45 to .70	.05	.05	3.0 to 3.75	.50 to 1.0	.25 †	.65 †	1.0 †		55	65	18	50	40	241 to 293	O.Q. 830°C. and T. 560–660°C.	Crank shaft. Impeller-Propeller hub bolts, Valve Washers, Cylinder studs, Cylinder head shrink band.
	Nickel Chrome Steel (for crankshaft)	.25 to .35	.30	.45 to .70	.05	.05	3.0 to 3.75	.50 to 1.0	.25	.65	1.0		60	70	18	50	40	269 to 321	Q.P. 830°C. and T. 550–600°C.	Crank shaft, Rocker arms, Gears.
2. S. 28	Air-hardening Nickel-Chrome Steel	.25 to .32	.30	.35 to .60	.05	.05	3.75 to 4.5	1.0 to 1.5	.25 †	.65 †	1.0 †		100	—	12	25	15	Min 444	A.H. 820°C. and T. 250°C.	Crank shaft gears.
S. 61	High Chrome Non-corroding Steel	Max .15	.50				Max 1.0	Min 12.0					35	45	25	50	45 x	152 to 207	O.Q. 940°C. and T. 600–750°C.	Exhaust pipes.
S. 65	65 ton Nickel-Chrome Steel.	.22 to .28	.30	.35 to .65	.05	.05	2.75 to 3.5	1.0 to 1.4	.25 †	.65 †	1.0 †		65	70	17	40	35	293 to 321	O.Q. 830°C. and T. 500–600°C.	Connecting rod. Rocker arms.
D.T.D. 43	Chrome Nickel Non-corrosive Steel.	Max .20	.60	Max .60			6.0 to 10.0	16.0 to 20.0				22	50 *		25		40		Hard rolled	Exhaust port studs.
D.T.D.49A	High Nickel-Chrome-steel (for Valves)	Max .55	3.0	Max 1.5			Min 9.0	Min 12.0			0 to 6						15	207 to 293	O.Q. 950°C. T. 650–700°C.	Valves.
D.T.D.91A	50 ton steel. (tubes)	Max .50	Max .30	1.5	.05	.05	Max 3.75					45	50		*b*Special Flattening Test				Cold drawn and blued	Tubes.

W.Q.—Water quenched after refining. O.Q.—Oil quenched. T—Tempered. A.H.—Air hardened.
*—45 tons if diameter is over 2in. †—Optional. x—25ft. lbs. for bars over 2in. diameter.
b—Flattening Test.—Flatten till sides of tube are separated by not more than 8 times thickness of wall or $\frac{7}{8}$″ bore whichever is the smaller.

fort is being made in England to standardize the steel practice, as shown by the recommendations of the British Engineering Standards Association, now the British Standards Institution, which are reproduced in Table 5, from the house organ of the Edgar Allen Steel Co.

Greater use is made of alloy steels in foreign cars than is usual in this Country except in heavy-duty units. The tendency in Europe is to use steel of lower carbon but greater alloy content; we find a steel with 0.40 per cent of carbon and 0.75 to 1.00 per cent of nickel much used for front-axle centers, connecting-rods and crankshafts, which are generally of water-quenched carbon steel on passenger-cars in this Country. This practice improves the hardening quality of the steel, so that oil quenching of these parts is prevalent in Europe. On heavy-duty jobs, 3.0-per-cent-nickel or nickel-chromium steel is used.

The tendency abroad for steering knuckles is to use 3.5-per-cent-nickel steel or a nickel-chromium steel similar to S.A.E.-3435, oil quenched, while in this Country the use of water-quenched S.A.E.-3130 or oil-quenched S.A.E.-3135 is typical. European transmission gears show a wide variety of practice. Case-hardened gears of 3.0 to 3.5-per-cent nickel, 5.0-per-cent nickel or the Krupp analysis of 4.5-per-cent nickel and 1.5-per-cent chromium are common. Oil-hardened gears are commonly made of steels containing 0.28 to 0.35 per cent of carbon, 1.50 per cent of nickel and 1.0 to 1.25 per cent of chromium. For heavy duty, the nickel is increased to 3.0 per cent.

One practice not found in this Country is the use of air-hardening steels for gears. A typical analysis is carbon, 0.30 per cent; nickel, 3.50 per cent; and chromium, 1.50 to 1.75 per cent. An addition of 0.15 to 0.25 per cent of molybdenum is made for the highest results. These steels are hardened by heating to 1600 deg. fahr., cooling in air and tempering at 400 deg., and they show a Brinell hardness of close to 500. One interesting variation, used in a French car, is to carburize this steel to secure a case of 0.005 to 0.010 in., the hardening being performed by removing from the carburizing box and cooling in air. Rear-axle pinions and ring gears usually are case-hardened, although air-hardened ring gears are used.

For rear-axle shafts, 3.0-per-cent-nickel and the oil-hardening chromium-nickel steels are common in Europe, and air-hardening steels are used for heavy-duty work. For large-diameter shafts, an alloy containing 0.30 per cent of carbon, 4.00 per cent of nickel, 1.25 per cent of chromium and 0.20 per cent of molybdenum, air hardened and tempered, gives a strength close to 200,-000 lb. per sq. in.

Automotive Research

Front-Wheel Alignment

Subcommittee Work and Conclusions Analyzed —Annual Meeting Report by J. M. Nickelsen

ON account of the variations in the front-wheel alignment of various cars as manufactured, excessive tire wear occurring in the field and the unsatisfactory methods used for correcting alignment, the Research Committee of the Society thought it advisable to appoint a subcommittee to make a study of the subject with the hope of procuring better conditions. It was desired to form a committee representative of manufacturers of cars, tires and steering-gears and of the service field. Therefore the following members were selected during the summer of 1928, their company connection being as indicated. Mr. Nickelsen was Chairman during the first two years and Mr. Lemon thereafter.

B. J. Lemon (*Chairman*)	United States Rubber Co.
W. B. Barnes	Auburn Automobile Co.
F. F. Chandler	Ross Gear & Tool Co.
C. P. Grimes	Grimes Brake Engineering Service
N. F. Hadley	Chrysler Corp.
O. T. Kruesser	General Motors Proving Ground
E. S. Marks	H. H. Franklin Mfg. Co.
J. M. Nickelsen	University of Michigan
A. R. Platt	A. R. Platt Co.
C. B. Veal	Society of Automotive Engineers

In attacking the problem, the Subcommittee received the cooperation of the General Motors Proving Ground. On account of the large number of cars purchased for and driven at the Proving Ground, that organization was able to secure for the Committee desirable information on the alignment of cars. Engineering specifications for the alignment of their cars were secured from the various automobile factories. New cars as received at the Proving Ground were first checked to determine whether the alignment came within the manufacturers' specified limits. In attempting to get this information, such instruments as were available were used. Difficulty was encountered in obtaining results that would check. The instruments were then modified and improved to the point where satisfactory readings could be made. A description of the instruments used is incorporated in an earlier report of this Subcommittee[1]. A large concrete surface-plate was made up on which the entire car could be placed, to facilitate alignment measurements.

Errors Found in Cars Tested

Of the cars received at the Proving Ground, engineering specifications were available on only 71. Following are the data on these as received from the manufacturers:

Caster Angle

	Number of Cars Left Side	Right Side
O. K.	14	14
Within ±½ Deg.	22	28

Steering-Knuckle-Pivot Angle

O. K.	0	0
Within ±½ Deg.	10	16
Within ±1 Deg.	30	34

Camber Angle

O. K.	19	13
Within ±½ Deg.	45	41

Toe-In

O. K.	30

After this preliminary check, the cars were driven and readings taken every 5000 miles, as it was desired to note the change in alignment in service. Changes noted after these cars had been driven from 5000 to 20,000 miles are summarized in the following tabulation, which includes some extreme examples:

Caster Angle

	Left Side	Right Side
Number of Cars Changing ½ Deg. or More in Service	37	37
One Car, for Which the Engineering Specifications Are 1½ to 2½ Deg.		
Car as Received, deg.	—1.1	—0.6
After 5000 Miles, deg.	3.3	3.3

Steering-Knuckle-Pivot Angle

Number of Cars Changing ½ Deg. or More in Service	24	31

Two cases of exceptional change are noted; in one the angle increased, in the other the angle decreased, as follows:

One Car, for Which the Engineering Specifications Are 9½ Deg.		
Car as Received, deg.	6.25	6.3
After 5000 Miles, deg.	7.0	6.9
One Car, for Which the Engineering Specifications Are 8 Deg.		
Car as Received, deg.	6.8	7.1
After 5000 Miles, deg.	5.8	6.1

Camber Angle

Number of Cars Changing ½ Deg. or More in Service	10	4
One Car, for Which the Engineering Specifications Are ½ Deg.		
Car as Received, deg.	0.35	0.3
After 5000 Miles, deg.	0.1	0.3

Out of 45 cars checked, the toe-in of 32 changed in service. One car, for which the engineering specifications called for a toe-in of 1/16 to ⅛ in., was received with a negative toe-in of 1/32 in. Before driving, this was corrected to 3/32 in., positive. After driving 5000 miles, the toe-in was again negative, 5/16 in.

The foregoing gives a general perspective of the variation in alignment of cars as received from the factories and of the changes that occur in some of them with very little mileage. Roadability and tire mileage were satisfactory when the cars were held within reasonable limits of their specifications.

Preliminary Conclusions of Committee

From these data the following five general conclusions were drawn up and submitted to the members of the Subcommittee for approval:

(1) More than one-half of the new cars examined at the Proving Ground for alignment were found not to meet the manufacturers' specifications of toe-in, camber, caster and steering-knuckle-pivot inclination.

(2) Much of the equipment for measuring toe-in, camber, caster and steering-knuckle-pivot inclination is still far from satisfactory.

(3) Certain practices connected with alignment readjustment, such as heating and/or bending of axle parts, are decidedly questionable and likely to do more harm than good. Damaged or defective parts should be replaced by new ones.

(4) The examination and testing of cars of various makes indicates that no single set of specifications can be drawn for general application to cars of all makes. The problems must be handled by each individual manufacturer for his own product.

(5) The manufacturer who designs and produces the car should be responsible for coordinating methods of measuring and correcting alignment in the field with those used in his engineering and inspection departments. The manufacturer must also consider the training of his field representatives in the correct application of the methods he has established.

Unanimous approval of these conclusions was not reached by members of the Subcommittee. Items (3) and (4) were the ones in question, particularly the former. Because of this difference of opinion, letters were sent to automobile engineers, including chief engineers of all passenger-car, steering-gear and axle companies, for their opinions relative to Item (3). A summary of the replies follows:

Hot Bending: no, 15; no, unless carefully heat-treated afterward, 1; yes, if not heated above 800 deg. fahr., 1.

Cold Bending: no, 4; no (qualified), 4; yes (qualified), 8; yes for axles, no for steering parts, 1.

The general qualification on cold bending was that the bend should not

[1] See S.A.E. JOURNAL, April, 1929, p. 440.

exceed 5 deg., which is equivalent to ⅞ in. in 10 in., and that the piece be inspected closely for cracks after bending.

Exception Taken to Hot Bending

One manufacturer submitted a comprehensive report in which were included a number of microphotographs showing the correct grain structure of steel, the grain structure of steel that had been mistreated and views of parts that failed in service because of rough treatment or overheating.

Because of the opinions received in reply to the questionnaire, Item (3) of the original report was revised to read:

(3) Damaged, kinked, badly deformed and defective parts should be replaced by new ones.

(*a*) Heating to accomplish the bending and straightening of axles and steering parts, as related to alignment readjustments, is condemned as dangerous practice.

(*b*) Cold bending and straightening of axles and steering parts, particularly of steering parts as related to alignment readjustments, is questionable practice. Cold bending of a part that is distorted more than 5 deg. should not be attempted. All parts that are bent cold should be examined carefully for cracks after bending.

That a few of the better service stations have equipment which enables them to hot-bend an axle or steering part and heat-treat it afterward so as to bring it back to its original condition is admitted; however, these are so few that the general practice should be condemned.

While Item (4) did not provoke the discussion brought out by Item (3), it did develop some difference of opinion. The view of the majority of the Subcommittee members was that the manufacturer must work out suitable specifications for cars being put on the market and that it would be out of place for the Subcommittee to make a recommendation for standard practice. In checking over the most recent engineering specifications available (those for 1931, shown in Table 1), it is to be noted that several manufacturers producing more than one car model find it best to specify different alignment for various models.

Recommendations for Manufacturers

From the data collected at the General Motors Proving Ground, it appears that the factories should maintain a better check on alignment of cars delivered to the customer. Attention should also be given to designing the parts so that the car will hold to specifications during reasonable mileage.

As to Item (5), the opinion of the Subcommittee is that the manufacturers, through their service departments, should give representatives in the field more complete and thorough information on the alignment of their product. Suitable equipment for this work should be recommended by them, so that satisfactory checks can be made and the cars brought within the limits specified by their engineering departments.

TABLE 1—ALIGNMENT SPECIFICATIONS FOR 1931 PASSENGER-CARS

	Total Toe-In, In.	Camber or Pitch of Each Front Wheel, Deg.	Caster Angle, Deg.	Steering-Knuckle-Pivot Inclination, Deg.
Auburn	1/8-3/16	2	1-2	7
Buick 8-50	1/8-3/16[a]	1-1¾	1½-2	9
Buick 8-60, 8-80 and 8-90	3/32-1/8[b]	1¼-2	1½-2	8
Cadillac, V-8, V-12	1/8-1/4	1½	2½-3½	8½
Cadillac, V-16	1/8-1/4	1½	2-3	8½
Chrevolet	0.080-0.119[c]	1¼-1¾	2¼	7 1/16
Chrysler 6	1/32-3/32	2	1½-2	7
Chrysler De Luxe	0-1/8	2	1½-2	7
Chrysler Imperial 8	0-1/8	2	1½-2	7
Cord	0-1/8	1½	−½-0	0
DeSoto 6	1/32-3/32	2	1½-2	7
DeSoto 8	0-3/32	2	1½-2	7
DeVaux-Hall	1/16	1¼	4	6⅔
Dodge 6	1/32-3/32	2	1½-2	7
Dodge 8	1/32-3/32	2	2-2½	7
Duesenberg	1/8-1/4	1	1-3	4½
Essex	±1/8	1	1 1/20	7
Ford	1/32-3/32	2	5	7
Franklin	0-1/8	2 (½ in.)	1	7
Graham 6	1/8-3/16	1	1½-2½	9
Graham 8	1/8-3/16	1½	1½-2½	7
Hudson	±1/8	1	1 1/20	7
Hupp C, H and U	1/32-3/32	1½	3	....
Hupp S and L	1/16-1/8	1½	3	....
Kissel 8-95	3/16	2	1½	6
Kissel 8-126	3/16	1	1½	7½
LaSalle	1/8-1/4	1½	2½-3½	8½
Lincoln	1/16-1/8	1	¾	7½
Marmon 16	0-1/16	1½	3⅓	7
Marmon 79	0-1/16	1½	3½	7
Marmon 88	0-1/16	1½	3	7
Nash 960, 970 and 980	1/8	1½	1½	7
Nash 990	1/8	1½	0	6
Oakland	0-1/8	1¾	1¾-2½	....
Oldsmobile	7/64	1¾ (1⅛ in.)	3½	9½
Packard	1/8	1½	1	9½
Pierce-Arrow	1/8-3/16	½-1½ (3/16-17/32 in.)	1¾	8
Plymouth	1/32-3/32	1½	1	7
Pontiac	0-1/8	1½	1½-2¼	7 1/6
Reo B-2	0-1/8	1½	3	7
Reo C	0-1/8	1½	3½	8
Rolls-Royce P-I	1/16	1	1¾	2½
Rolls-Royce P-II	1/8	1	2½	2½
Studebaker 6 and Dictator	1/16-1/8	1	1-2	8
Studebaker Commander and President	1/16-1/8	1	1-1½	8
Stutz	1/4-5/16	1	2½	7½
Willys 6 and 8	1/8-3/16	2	1-2	7½
Willys-Knight	1/8-3/16	2	1-2	7½

[a] With demountable wood, wire or disc wheels, 7/32-9/32 in., measured between tires.

[b] With demountable wood, wire or disc wheels, ⅛-3/16 in., measured between tires

[c] Measured between edges of felloes.

The Subcommittee believes that urgent need exists for supplying promptly to the service stations alignment-specification data covering all cars as produced. Many of the data used in the past have been obsolete on account of the difficulty of securing the latest specifications. It seems desirable that such data be furnished to trade journals for publication and to other organizations that might wish to avail themselves of it.

Discussion of the Report

Members of the Subcommittee, car engineers, tire service men and others at the Annual Meeting discussed the foregoing report. A few representative contributions to the discussion are abstracted in the following paragraphs.

B. J. Lemon, Chairman of the Subcommittee during the last two years, remarked that the work was begun at the request of the tire companies because of irregular tire wear and the scarcity of published information on front-wheel geometry to constitute an accurate basis for making corrections. The need for research work on alignment was illustrated by an experience with a test car, the alignment of which, after 10,000 miles of service, was corrected by an alignment expert who applied a blow-torch to bend the steering parts. After operating the car for 10,000 miles more, the parts were returned to the car maker, who reported them to be only one-half as strong as they originally were.

Mr. Lemon expressed the belief that a general improvement has been made in front-end geometry since the work of the Subcommittee began. This improvement he ascribed to a reduction in camber and perhaps in toe-in, with more attention given to caster angle. Improvement in front-wheel brakes also has contributed to a reduction in front-tire wear.

J. W. Shields, field engineer of the Firestone Tire & Rubber Co., called attention to the items in the report which showed that one-half of the new cars examined at the Proving Grounds were outside the alignment limits of the manufacturers' specifications. The correction of this condition does not properly belong to the tire man, but he has been obliged, in self-defense, to install apparatus for measuring and attempting to correct the condition. Diplomacy is necessary if the tire man is to correct the alignment of a virtually new car in a way that will satisfy the customer without causing ill feeling with those who made and sold the car.

When high-pressure and solid tires were common, nearly all motor-trucks and motorcoaches were made with a high degree of camber. When balloon tires were applied, such camber caused rapid wear, and it was often necessary for the tire men to change the camber and the toe-in. Mr. Shields' experience indicates, he said, that the ideal condition for tire wear, disregarding problems of shimmy and hard steering, would be to set the camber and toe-in so that both will be zero when the car is operating under load at its normal speed.

Tests Indicate Toe-in Causes Wear

George M. Sprowls, manager of the highway transportation department of the Goodyear Tire & Rubber Co., reported tests on the effect of camber and toe-in during which the tires on 45 cars were observed. These cars were divided into three equal groups having cambers of 0, 2 and 4 deg. respectively. Each group was subdivided into three groups of five cars each, having toe-in settings of 0 to 1/16, 3/16 to ¼ and ⅜ to 7/16 in. respectively. The caster angle was kept constant.

All these cars were operated for a uniform distance of about 20,000 miles, and the amount of tread wear was measured. The least wear was found on the group having 0-deg. camber and 0 to 1/16-in. toe-in. Taking the wear on this group as 100 per cent, the wear

on all the groups, in per cent, was as follows:

Camber, Deg.	0	2	4
Toe-in, In.			
0-1/16	100	112	120
3/16-¼	115	121	122
⅜-7/16	158	132	148

This test indicated that toe-in was the item that needed most careful watching to keep the tire wear to the minimum, although camber cannot be said to be without effect. Mr. Sprowls also observed several cases in which both toe-in and camber were very small but uneven wear occurred on the treads of the tires. He is looking for an explanation of this.

Advocate Standardizing the Settings

A. R. Platt, a member of the Subcommittee, expressed the belief that it should be possible to calculate the toe-in required for given camber and caster angles. Checking toe-in without first checking the camber and caster angles he considers useless, so it is necessary to supply the workers in the field with some form of instrument that will automatically calculate the toe-in required and eliminate the workman's guess. Records of more than 2000 cars indicate to him that usually the camber or caster or both are incorrect, and the chances are slight that the workman will make the right guess as to what the toe-in should be.

Mr. Platt commented on the small variation in the camber and caster angles reported in Table 1 and advocated standardizing on the average of those figures. With these angles standardized, a standard toe-in setting could be adopted which would make it unnecessary to rely upon the judgment of the service mechanic in setting toe-in.

Edgar Shay, of the Chrysler Corp., advocated standardizing the camber and caster. He recommended that both of these angles should be 1 deg., and that the toe-in should be set with the aid of some instrument embodying something like a movable board that will indicate any abrasive action.

J. F. Winchester, of the Standard Oil Co. of New Jersey, stated that he considered the report valuable because it definitely demonstrates that roadability and tire mileage are satisfactory when the cars are held within reasonable limits of their specifications. This shows that the engineers have done their work well; apparently better factory inspection methods is the need. He believes, he said, that suitable specifications should be furnished by the manufacturers to reputable service organizations, which usually have personnel sufficiently well trained to make alignment adjustments for a reasonable charge. The past difficulties have been that the fundamentals have not actually been portrayed and adequate engineering information on definite models has not always been supplied promptly by the service departments of the large manufacturers.

Council Hears Favorable Report on Membership

AT a meeting held in New York City on May 11, the Society's Council showed particular interest in and appreciation of the results of the Get-Your-Man campaign for new members. It was reported that the applications thus far received exceed the 200 mark. Plans were accepted for a vigorous continuation of the membership enterprise, which will close officially on July 31.

The Council directed that, beginning with dues for the coming year, starting Oct. 1, 1932, the members will be billed for the full amount, but with the privilege of paying their dues in half-yearly installments.

Considerable thought was devoted to proposals for the enlargement of the Society's activity designed to give all members greater participation privileges and increased personal activity, with resulting benefits to themselves; also to add a new large group of qualified men and to provide for the further growth and continued service of the Society. The ideas behind these plans included an extension of Society meetings to communities that do not enjoy the advantages of meetings at present.

Fifty applications for individual membership and 30 transfers in grade of membership were approved. Seven resignations were accepted and three reinstatements to membership were approved. Thirty-six applications, one reinstatement, one reapproval and one grade transfer, on which the Council had acted by mail vote, were confirmed.

The appointment of C. C. Hinkley for service on the S.A.E.-A.S.M.E. Diesel-Fuel Research Committee was approved.

Grosvenor Hotchkiss was appointed to act as the Society's representative on the Division of Engineering and Industrial Research of the National Research Council to serve for three years, beginning June 30, 1932. Mr. Hotchkiss will fill the vacancy left by Edward P. Warner, whose term of office expires on June 30.

H. F. Huf was appointed to act as the Society's representative on the Noise-Measurement Sectional Committee of the American Standards Association.

The Council approved of having the Society sponsor, without financial obligation, a six-volume work on Aerodynamic Theory, edited by Dr. W. F. Durand; this being a joint sponsorship with the Daniel Guggenheim Medal Fund and the Engineering Societies Monographs Committee.

The next meeting of the Council will be held at White Sulphur Springs during the Summer Meeting period.

Prepare for Prosperity

(*Concluded from p.* 11)

rial were mailed to the membership on May 20, the reverse side of the sheet giving information about railroad accommodations and reservations contained flying data, for the convenience of members who plan to fly to the Summer Meeting.

Entertainment for Ladies

Many of the ladies who in the past have attended the Society's Summer Meetings at White Sulphur Springs have expressed great satisfaction at the delightful surroundings and the numerous opportunities for enjoyment, and it is confidently believed that the 1932 meeting will furnish no exception in this respect. As usual, bridge will be arranged each forenoon for those ladies who wish to play, and other recreational facilities will include golf, tennis, archery and swimming, as well as dancing each evening after the adjournment of the technical session, and a grand ball on Thursday evening.

Use That Reservation Blank!

Applications for hotel reservations have been coming in daily at the Society's headquarters ever since the first blank was mailed with the Meetings Bulletin, late in April, and especially since a second blank was sent out, on May 20, for use by those who had mislaid or for some other reason failed to use the first blank. It is not yet too late to secure acceptable accommodations at the hotel if the second blank is filled out and returned at once. Members who are planning to attend the Summer Meeting, but have not yet made application for reservations, are urged to do so at once, mailing the blank with check to the offices of the Society.

Meetings Calendar

General Meetings

Summer Meeting—June 12 to 17

Greenbrier Hotel, White Sulphur Spring, W. Va.

Aeronautic Meeting—Aug. 30 and 31

Hotel Statler, Cleveland.

In connection with the Aeronautical Chamber of Commerce of America during the National Air Races.

Production Meeting—In Week of Oct. 3

174th Regiment Armory, Buffalo.

In cooperation with the National Metal Congress and Exposition.

Transportation Meeting—Oct. 4 to 6

Royal York Hotel, Toronto, Canada.

Transportation Engineering

Powers of a Registrar Outlined

Massachusetts Department Head Indicates Present Scope of Motor-Vehicle Control

MORGAN T. RYAN, registrar of motor-vehicles for Massachusetts told members and guests of the New England Section recently that driving a motor-vehicle has been held by the Supreme Court to be, not a Constitutional right, but a privilege that may be granted or revoked. The law classes the motor-vehicle as dangerous, and the Legislature has delegated to the Registry of Motor-Vehicles the power to grant and to revoke drivers' licenses. The following extracts from Mr. Ryan's address illustrate the comprehensive nature of the control exercised.

No real conflict can exist between the Registrar and the courts, since each is exercising separate and distinct powers granted by the Legislature. Each approaches a different object by different means. The court seeks to determine whether the defendant has violated the criminal statute and is, therefore, deserving of punishment by fine or imprisonment. The registrar's purpose is to ascertain whether the operator's conduct constitutes improper operation sufficient to justify the withdrawal for a time of his privilege to operate a motor-vehicle.

The registrar has no concern with actions to recover money damages, and to suspend or revoke a license or registration merely to compel the settlement of such a claim would be an abuse of his authority. Many complainants seem to be unaware of this distinction and attempt to use the registrar's office as a collection agency. This does not mean that the registrar will refrain from taking action where money damages are involved, but that he will determine such cases solely on the basis of the fault of the operators involved and discount complaints impelled by improper motives.

Authority to Suspend Licenses

The registrar's authority to suspend licenses is very broad. He may suspend the license of any person in his discretion, and without a hearing, whenever he has reason to believe that the driver is incompetent to operate motor-vehicles or is operating improperly or so as to endanger the public. This great power is given to him because of the necessity that arises in the interests of public safety, to allow him to remove from the highways at once a person whose further operation of a vehicle might prove dangerous to the public. It is a power that is very carefully exercised by the registrar and only upon recommendation from motor-vehicle inspectors of his own department or responsible police officials. Moreover, a hearing is immediately granted upon request to any person whose license is suspended or revoked, thus allowing him an opportunity to show cause why his license should be restored to him, except in those cases following court conviction in which the registrar has no discretion. No license is suspended or revoked upon complaint of any person other than the foregoing except after a hearing given to the accused or after investigation by a motor-vehicle inspector.

Many persons who have been deprived of their licenses appear before the registrar to present their cases upon purely personal grounds, as, for example, that they need the licenses in their business. This is not sufficient grounds for the return of a license. Personal reasons cannot be given any considerable weight by the registrar, since his duty to act is not alone to the individual who has been deprived of his license but to the public at large, which might be affected as a result of operation by the person requesting reinstatement. The vast number of people who lawfully use the highways have rights far outweighing any personal interests of the individual.

Control Procedure for Motor-Trucks

On account of their great weight and size, motor-trucks constitute an exceptional hazard to other users of the highways and should, therefore, be operated in the most careful manner. Operation at speeds that do not permit of proper control under the conditions existing, especially when children are on or near the highway, is a frequent cause of serious accidents involving trucks. When such operation is accompanied by faulty brakes, the act amounts to criminal negligence and is generally so held by the courts.

A practice, lately apparently on the increase, of transporting picnic parties on trucks, resulted in several very serious accidents in the summer of 1931. This is a dangerous practice which should be discontinued, and we should do all in our power to discourage it. Trucks are not fitted and equipped for the safe carriage of passengers, nor do they carry the proper insurance to afford protection to their passengers in the event of accident.

Every part of a truck—the frame, springs, powerplant, transmission, rear end, axles, steering-gear and brakes—is designed by a competent engineer with a definite load to be carried as the basis of his specifications as to size and strength. To the actual requirements, he adds a safety factor of a definite percentage. Every pound added to the weight that the truck was designed to carry narrows this margin of safety. Therefore the provision against loading in excess of the manufacturer's rating is strictly enforced.

Motorcoach drivers have the responsibility of all operators of motor-vehicles to other users of the highways, together with their tremendous responsibility for the lives and safety of their passengers. This calls for the highest degree of competence and carefulness. The driver's conduct on the road will be judged on this high standard, and no person should undertake to drive a motorcoach unless he is willing to assume this responsibility in full. Operators should use great care in drawing up time schedules. Too close a running schedule is a constant source of anxiety to the driver and, when he is delayed by unforeseen circumstances, constitutes a temptation to him to take chances in traffic. No motorcoach driver is ever justified in taking chances with the lives or safety of his passengers.

Periodic Inspection Essential

Massachusetts is now one of four States that has legislation requiring periodic inspection of the equipment of all motor-vehicles. Just how such legislation can be most effectively executed is a problem with which we are still wrestling and which can be successfully solved only by careful study illuminated by experience.

Just how important is the inspection of equipment and what worthwhile results can we expect from it? Will such inspections reduce accidents? Nobody knows just how many accidents are prevented or avoided by the detection and elimination of faulty equipment that would not otherwise be corrected. Neither do we know how many accidents are prevented or avoided by the compulsory examination of all applicants for licenses, but that the number must be large will be admitted.

It is a fact that in Massachusetts, in the year 1920, immediately following the adoption of a new rule requiring the examination of all applicants for licenses, we experienced a 17.3-per cent reduction in fatal accidents. We all realize that the human factor is of much greater importance than the mechanical. Nevertheless, our investigations prove that defective equipment is a frequent cause of accident and one that is comparatively easy of detection and correction. With the death rate due to the motor-vehicle constantly increasing in the United States and reaching in 1931 the staggering total of 35,000 lives, no possible procedure that holds hope of remedy should be overlooked. Because of our continuous efforts to promote safety, Massachusetts has one of the best accident records of any of the States, considering the number of motor-vehicles registered and the population.

Periodic inspections are now on trial in Massachusetts and in several other States. Probably it will require several years to show whether the results obtained compensate for the trouble and expense to which they put the State administration and the public; but we should not shrink from any effort that will aid in protecting human lives.

News of the Sections

See Bodies in the Making

Milwaukeeans Visit Seaman Plant and Dine and Hear Four Papers

MAY 4 was a great day for members of the Milwaukee Section, 75 of whom visisted the Seaman Body Corp. plant in the afternoon and dined in the evening at the Milwaukee Athletic Club. An excellent technical session followed, at which 150 members and guests listened with interest to the presentation of four papers on production, engineering and design. At a short business session announcement was made of the election of Section officers for next year as follows:

Chairman—P. C. Ritchie, Waukesha Motor Co.

Vice-Chairman—P. W. Eells, Le Roi Co.

Secretary—W. B. Pusey, S K F Industries, Inc.

Treasurer—C. E. Frudden, Allis-Chalmers Mfg. Co.

Body Plant Shows Much Engineering

The visit to the Seaman plant included inspection of the woodworking shop, where the impregnation of each part with Tri-Treat proved of great interest, this method of "vaccination" to assure longer life being a recent development; the steel-drawing department, where large and small presses were in operation and the method of rapid handling of the numerous dies was observed with interest; the welding department, where gas and electric spot, flash-butt, arc and gun methods are employed; the progressive-assembling department; and the finishing department, where gun-spraying of paint and modern methods of striping reduce the finishing time from weeks to hours compared with the original painting practices in the industry.

The plant structures have a floor area of 1,500,000 sq. ft. and the corporation normally employs 6000 persons. The latest equipment is installed and the methods used in assembling 1400 parts into an automobile body in the shortest time reveal the amount of engineering that is necessary in this branch of the automobile industry. The finished product, though made up of many individual pieces, comes off the line with the appearance of a single sheet of material.

Body Production and Car Design

At the technical session, H. H. Seaman, president of the corporation, contrasted modern body-building methods with those of the early days, saying that certain labor operations have been reduced in cost from $4 to 1½ cents and that now the total labor cost per body is from $30 to $50. according to the size and model of the body. Use of "high solid lacquer" in spray guns has reduced the finishing time from three or four weeks to a matter of hours. Notable progress is represented, he said, in the corporation's composite wood and steel bodies in which the wood is treated with a preservative. Incorporated in a body are 200 wood parts on which an average of 10 operations are required, and each steel part requires from 30 to 40 operations.

The Trend in Automobile Designing was the title of a paper given by C. H. Bliss, vice-president and sales director of the Nash Motors Co., who said he was anxious to impress those present with the several developments in the new Nash cars that are the result of "that designer known as Public Opinion." Major factors today, he said, are appearance, comfort, durability and price. Style changes surpass in rapidity those in the millinery trade and have resulted in 27 models with 168,000 possible combinations of bodies, finish, hardware and upholstery, according to Mr. Bliss. This fact complicates production problems and causes delays in filling specific orders, with a consequent slowing up all along the line.

Higher driving speeds have necessitated the angular windshield, the V-radiator and lower bodies. Other results of current public demand, continued the speaker, are the ride control, the X-frame, body insulation, central chassis lubrication, centrifuge brakes, aluminum pistons and connecting-rods and free-wheeling.

Meade F. Moore, chief engineer of the Racine division of the company, pointed out some of the highlights of the present series of Nash cars, such as the advantages of the dual frame, twin ignition, alloy pistons and connecting-rods and worm drive. The lubrication system of the worm drive, he said, necessitates a close-mouthed cartridge-type unit for maintaining the oil film. Through the use of light-weight pistons and rods, a reduction of 40 deg. fahr. in oil temperature has been obtained in certain tests. Twin ignition is more advantageous in the overhead valve engine than in the L-head type, said Mr. Moore; the two spark-plugs in a cylinder are not always fired simultaneously and the correct amount of lag in each is a matter of experimentation with different designs of engine.

Among those who took part in discussion on the papers were J. R. Frantz, R. I. Dick, P. C. Ritchie, C. E. Frudden and J. B. Armitage.

"Ket" Appeals to Engineers

Tells the Detroit Section That They Can Get America Out of the Depression

ONE of Detroit Section's largest local gatherings turned out on the night of May 9 to hear C. F. Kettering give one of his characteristic entertaining talks. His topic was Engineers Have Lots To Do, and those who have read recent articles by Mr. Kettering in the *Saturday Evening Post* on the part that research and engineering can and should do to get the Country out of the depression can imagine something of the burden of his address to the Section.

Attendance at the members' dinner at the Book-Cadillac numbered 378, and 72 came later to enjoy "Ket's" humor and serious commentaries. The Detroit Section's High Hats provided musical entertainment for the occasion.

Officers of the Section for the administrative year 1932-1933 were elected at a short business session. They are:

Chairman—E. V. Rippingille, General Motors Corp.

Vice-Chairman representing Aeronautics—Ralph N. Du Bois, Continental Aircraft Engine Co.

Vice-Chairman representing Bodies—John W. Votypka, LeBaron-Detroit Co.

Vice-Chairman representing Passenger Cars—George B. Allen, Dodge Brothers Corp.

Vice-Chairman representing Student Activities—Harry T. Woolson, Chrysler Corp.

Secretary—Vincent P. Rumely, Hudson Motor Car Co.

Treasurer—Ferdinand W. Marschner, New Departure Mfg. Co.

Engineers Can Correct Our Ills

Mr. Kettering emphasized particularly his firm conviction that engineers, with their exact type of reasoning, are the men who are most capable to correct the economic evils that are responsible for depressed conditions of business. He said that the causes for our present ills are many and each cause has its coterie of exponents, one particularly strong group believing that over-mechanization is the sole cause of a business depression such as we are experiencing at present. If over-mechanization is the cause, he asked, how can we account for the troubles in Spain and India, which are not in any way industrial countries?

During the World War we developed

many new things for use in the war, and the tempo that was then set was full speed ahead. This tempo was not normal and it continued too long, asserted the speaker. Following the war, new industries were developed and super-exploitation and inflation carried the economic situation beyond the elastic limit. Mr. Kettering decried the tendency toward super-exploitation, which he defined as overdoing the same kind of thing. He illustrated this by calling attention to the common philosophy that, if one skyscraper or one gigantic hotel is a good thing, a whole lot of these same things will be so much the better. The result of this, of course, is over-expansion and resultant diminishing of returns. "Don't try to run the world too far in advance," he cautioned.

Drawing a similarity between economic conditions and chemical phenomena, Mr. Kettering mentioned the existence of optimums in solutions; for example, certain chemical combinations will progress to a certain optimum point, after which a continuance of the causes of the phenomena will bring about a diminishing rather than an ever-increasing result. People are not conscious of these optimums in business; they think that, if 1 tower is good, 10 will be 10 times as good.

Over-Exploitation to Blame

Continuing, Mr. Kettering said that the engineer is in no sense responsible for present conditions but that over-exploitation rather than over-mechanization is to blame.

New things are needed. New side-lines should be developed. Dunlop must have been a brave man to have dared to equip a vehicle with rubber tires, thinks "Ket," when it was already known that nothing but steel could serve the purpose. Many new things have been developed because the inventor did not know that there was no chance of succeeding. Many people feel that they can pull out a slide rule, give it a couple of slips and the answer is "No." If there is any place where nothing can be done, it is that place where everything has been reduced to a certainty and the formulas have all been written.

Other characteristic statements made by the speaker were as follows:

There are great possibilities for artificial rubber. When nature made rubber trees, she didn't have the ballon tire in mind.

Rubber, petroleum and steel are the three important fundamental elements of industrial progress. Development in these materials has a great distance to go.

Engines today are not very efficient. There is enough energy in a gallon of gasoline to drive from Detroit to St. Louis.

As in the industries of electric lighting and telephony, the greatest progress has come in many lines during the second 25 years of the industry.

Mr. Kettering stated that he does not believe in any standards that can deter progress and new development. He said that he would sooner trust our economic problems of today to a bunch of engineers than to our present Congress. He defined "status quo" in the words of the colored preacher whose definition was "the mess we're in."

Research Work at Purdue Observed by Indianans

INDIANA Section's April meeting was a field day at Purdue University in West Lafayette, Ind., on the 21st. Seventy members and their guests spent the afternoon visiting the laboratories of the university under guidance of the engineering staff and observing research work that is under way in the automotive, electrical, chemical and mechanical laboratories. After this interesting inspection, dinner was served to a party of 80, and in the evening seven brief papers prepared by students were delivered at the technical session, which was attended by 120. This participation by students in a regular Section meeting establishes a record in the Society, in the opinion of Prof. H. M. Jacklin, Chairman of the Indiana Section.

A. A. Potter, dean of engineering at the university, presented the opening paper at the session, entitled The Place of Research in Colleges. This was followed by the student papers in the following order, each being presented by the author first named.

Effects of Cooling Pistons, by C. R. Potter and R. G. Hummer

A New Type of Torsiograph, by L. S. LaGros and J. M. Hildabolt

Tests of Fuels, by A. E. Weaver and M. Bennett

Testing a Tractor and a Truck, by Lieut. C. B. Magruder, Field Artillery, U.S.A.

Moments of Inertia and Radii of Gyrations of Automobiles, by R. M. Blackburn and R. E. Woodburn

Forces and Frequencies of Vibration in Three Directions, by T. A. Askern and H. C. Wheaton

The Shake Table and Its Effects on Human Beings, by S. Liddell

Pittsburgh Season Ends in Frolic

POURING rain failed to dampen the ardor of 75 members of the Pittsburgh Section who got together for dinner and 11 late arrivals for the third annual frolic of the Section at the Fort Pitt Hotel on May 10. After a brief business session following the dinner, the evening was given over to entertainment by a humorist and to professional dancing.

At the business meeting, retiring Chairman B. H. Eaton reviewed very briefly the eight monthly meetings held by the Section in the season that just ended, mentioning the subjects and the speakers at each meeting. The election of the following officers for the 1932-1933 season was then announced:

Chairman—Charles R. Noll, Gulf Refining Co.

Vice-Chairman—Murray Fahnestock, *Ford Dealer & Service Field.*

Secretary—Charles F. Kels, West Penn Power Co.

Treasurer—Robert N. Austen, Iron City Spring Co.

The newly elected Chairman then took the chair upon invitation from Chairman Eaton, and Mr. Noll introduced John Orr, Section Chairman during the 1930-1931 season, who presented to Mr. Eaton, on behalf of the members, a little token to remind him that his efforts in the interests of the Section through the last season were greatly appreciated.

Chairman Noll introduced Dr. Hugh Crockeau as the loud-speaker of the evening, whose topic was What's Wrong with Service—and with Everything Else? Dr. Crockeau explained how to take a hill on high without shifting one's gears, and many other inaccuracies of the formula *p x q u d*. Discussion soon became animated, with not more than four men talking at once. When finally unwigged, the speaker was revealed as a well-known humorist.

Door prizes that were then awarded proved a more profitable form of speculation than dabbling in the Stock Exchange.

Peppy acrobatic and Apache dancing followed, illustrating the difference between static and dynamic balancing. The general hilarity made the introduction of a troupe of dancing and singing girls difficult and they soon realized the truth of the saying that "it's a wise girl who is seen and not heard."

Motion pictures showing the activities at last year's Summer Meeting were run off, Chairman Eaton explaining the advantages of attending the meeting this month and telling of the good times enjoyed by the Pittsburgh members who attended last year, several of whom were recognized in the pictures.

Chicago Section and Aeronautical Chamber Joint Meeting

TWO excellent aircraft addresses were given before an audience of nearly 100 at the May 3 meeting of the Chicago Section, which was held jointly with the Aeronautical Chamber of Commerce of America. The speakers were L. D. Seymour, vice-president of the United Air Lines; and V. R. Jacobs, of the Goodyear Tire & Rubber Co. and the Goodyear-Zeppelin Corp.

The technical session followed a members' dinner attended by 57 members and guests, at which entertainment was provided. At a business session of the Section the tellers of election reported the election of officers for next year as follows:

Chairman—L. V. Newton, Byllesby Engineering & Management Corp.

Vice-Chairman — Harold Nutt, Borg & Beck Co.

Secretary—R. E. Wilkin, Standard Oil Co. (Indiana)

Treasurer—Harry F. Bryan, International Harvester Co.

An Engineering Industry

Mr. Seymour, in his paper, referred to the contributions of both the Aeronautical Chamber and the Society to the advancement of the science of aeronautics and stated that this generous and essential contribution must continue if the industry is to advance as rapidly in the future as it has in the past. Aviation is an engineering industry, he said; few fundamental principles other than those embodied in the Wright airplane flown at Kitty Hawk, N. C., in 1903 have been added to our knowledge of heavier-than-air flying, the improved capabilities of present airplanes being

due almost entirely to painstaking engineering study, scientific research and the application of many standards and recommended practices of the Society.

Mr. Seymour particularly emphasized the continuous efforts of the Society in disseminating the best of that which is learned for the benefit of all. The airplane builder has benefited from the engineering talent of the great automotive commercial organizations that have contributed such items as starters, generators, ignition, instruments, wheels, tires, brakes and even processes for treatment of materials.

Because of small sales of airplanes to the public and the relatively high cost of the craft, the speaker pointed out that the cost of scientific research that is necessary to continued development must continue to be borne in part by the Government as it has under the five-year procurement program, now coming to a close.

Mr. Jacobs covered in a most interesting talk the field of activity of both heavier-than-air and lighter-than-air craft, and at the conclusion of his lively address received the greatest outburst of applause ever given at a Chicago Section meeting. Owing to the length of the address, which covered the subject thoroughly, the usual discussion was dispensed with.

A pleasing and very timely feature was the showing of motion pictures of the U. S. S. Akron, which was being prepared at Lakehurst, N. J., for its flight to the Pacific Coast.

Syracusans Turn to Water Sports

MOTORBOATS and fly-rod making occupied the thoughts of members of the Syracuse Section at the monthly meeting on May 17, when 33 members gathered in the Hotel Syracuse to hear and discuss two papers on these subjects.

Volney E. Lacy, designing engineer of the Rochester Boat Corp., of Rochester, gave a paper on the topic, Recent Developments in the Design of Small Boats and Marine Engines; and George F. McDuffee, president of the Fred D. Divine Co., of Utica, N. Y., spoke on The Art of Fly-Rod Making.

Prior to presentation of the papers, officers of the Section for the coming administrative year were unanimously elected as follows:

Chairman—L. W. Moulton, production engineer, Manufacturers Consulting Engineers.

Vice-Chairman—Carl T. Doman, research engineer, H. H. Franklin Mfg. Co.

Secretary—Richard M. Wright, assistant manager, Hubert J. Wright, Inc.

Treasurer—Melville R. Potter, service manager, Allen Cadillac Corp.

Electrical Session at St. Louis

THE April meeting of the St. Louis Section was held jointly with the Electrical Board of Trade on April 27 at the Hotel Statler and was attended by 325 members and guests of the two organizations. The speaker of the evening was Dr. Phillips Thomas, of the Westinghouse Electric & Mfg. Co., who presented an interesting address and demonstration on Electrons at Work and Play.

Fechet Says More Power Is Needed

Tells Met Section and A. C. A. A. That Liquid-Cooled Aviation Engines Are Required

MAJOR-GEN. JAMES E. FECHET, former chief of the Army Air Corps, was the major attraction at the joint meeting of the Metropolitan Section and the Aeronautical Chamber of Commerce of America on May 19. The second speaker was John S. Allard, vice-president of the Curtiss-Wright Corp. The meeting, which was held as usual at the A. W. A. Clubhouse in New York City, was attended by 118 members of the two organizations and their guests and followed a dinner at which 73 were present. At a brief business session the election of the following officers for 1932-1933 was announced:

Chairman—F. H. Dutcher, instructor in mechanical engineering, Columbia University

Vice-Chairman—A. F. Coleman, manager, motor-vehicle department, Standard Oil Co.

Vice-Chairman for Aeronautics—F. C. Mock, research engineer, Bendix Research Corp.

Vice-Chairman for Marine Division—William E. John, manager, New York City office, Sterling Engine Co.

Secretary—J. Edward Schipper, Sutton & Schipper

Treasurer—C. H. Baxley, mechanical engineer, Vacuum Oil Co.

Some Needed Powerplant Developments

General Fechet told his audience that while several foreign countries have more military airplanes than the combined air services of this Country, the British Alert single-seat pursuit plane is the only foreign type that is reported as being superior in performance to the corresponding type in the Army Air Corps, but, considering all conditions of military operations, the American pursuit classification as a whole has the best performing airplanes in the world. However, to maintain our superiority and obtain a margin of increased performance, the aircraft industry must provide improved powerplants of greater output. This applies both to military aviation and to commercial aviation, which cannot hope to establish itself on a sound financial basis without engines of greater power, said General Fechet.

The industry should realize the importance of furthering the development of liquid-cooled engines; the Army and the Navy should have liquid-cooled engines that are as reliable as present air-cooled engines, and this is entirely possible. The many refinements in the airplane structure proper in the last two years have contributed from 20 to 25 per cent of the great increase in speed of the heavier types of military craft, and the rest of the increase is the result of powerplant improvements. However, the problem of the immediate future is the providing of reliable engines capable of developing from 600 to 1000 hp. at all altitudes up to 30,000 ft., which will fit into the various types of airplane having extremely high speed and capable of still greater increases. The liquid-cooled engine, continued the speaker, must be considered, since the V-engine plus radiator offers less resistance than the air-cooled type and should lend itself to power increases more readily than the radial type.

Supercharging and Other Requirements

With the available special fuels and an engine designed for use of high-temperature liquid coolants, the combination of two stages of supercharging is believed possible. The pilot should be able to use the geared-type supercharger for ground boosting and cut in the exhaust-driven type for flying at great altitudes. Forceful realization has come to the Air Corps within the last few months that the exhaust-gas-driven supercharger is thoroughly practical and a most efficient means of increasing power at all altitudes.

Provision for reduction gears of various ratios for all engines should be made available to military-airplane constructors, asserted General Fechet, as the fact has been definitely proved that reduction gearing increases the speed by 6 to 12 m.p.h., and this is increasingly important at great altitudes.

A third requirement of extreme importance is the controllable-pitch propeller, as the problem of getting heavy planes off the ground with full load is great.

Elimination of the carbureter and adaptation of fuel injection also must be taken into consideration by the manufacturers of both air-cooled and liquid-cooled engines, according to General Fechet, and the ignition system must be reconsidered carefully because the supercharger introduces new problems. Radio equipment should be installed in both military and commercial craft, and this necessitates shielding, generators and other apparatus. Fuel systems, control of oil temperature, radiators, engine mounts and vibration reduction are other items that need study.

Allard Discusses Aviation

Aviation and Its Relation to Engineering was the topic on which Mr. Allard spoke. He reviewed the marketing problems for airplanes and said that two phases of aviation which he thinks assure its future and point to the necessity for continued exhaustive research and development are National defence and transportation. The condition now faced by the industry is not unlike that of 15 years ago, when appropriations for the Army and the Navy were needed for engineering and procurement programs. Progress in air transportation, said Mr. Allard, has been due to the engineering development of aircraft and engines and to support by the Post Office Department through its mail contracts. In 1931 the transport lines flew a total of 47,000,000 miles and carried 522,000 passengers and 9,640,000 lb. of mail; and these fig-

ures are being increased almost daily in astonishing amounts.

Figures were given to show that, with the ending on June 30, this year, of the five-year Army procurement program, the Army has only three-quarters of the number of planes needed to maintain the number of serviceable planes called for by Congressional Act. And at present the Country stands in fifth place among the air forces of the world. In view of the facts, the speaker appealed to his hearers to insist actively that Congress take the necessary steps to assure the carrying on of aviation development and the building up of one of the most important arms of our National defence.

Aircraft and Truck Maintenance Discussed at Los Angeles

ONE hundred members and guests of the Southern California Section assembled at the Engineers Club in Los Angeles on May 20 for the Section's maintenance meeting. The members' dinner and accompanying entertainment, provided through the courtesy of the Gilmore Oil Co. and the Electric & Carburetor Engineering Co., was attended by 76, and 24 more came later to hear the papers presented and discussed.

The first paper, on Aircraft-Engine Maintenance, was prepared jointly by W. E. Thomas, president and general manager of the Pacific Airmotive Corp., and Roy Kidd, foreman of the same company.

Edwin C. Wood, superintendent of transportation for the Pacific Gas & Electric Co., of San Francisco, presented his paper on Fleet Maintenance, in which he urged closer cooperation between the vehicle manufacturers and the maintenance men in the field.

Those who took prominent parts in the discussion were Stanley S. LaSha, of the western office of the Aeronautics Bureau of the Department of Commerce; E. Favary, consulting automotive engineer in Los Angeles; E. E. Tattersfield, president of the Electric & Carburetor Engineering Co.; and Van W. Dennis, superintendent of transportation for the Pacific Telephone & Telegraph Co., at Sacramento.

Boat Speed of 150 M.P.H. Possible, Canadians Are Told

SPEED boats could be built to attain a speed of about 150 m.p.h., in the belief of H. Ditchburn, president of Ditchburn Boats, Ltd., of Gravenhurst, Ont., internationally known designer and builder of speed craft, who was the principal speaker at the last regular meeting of the Canadian Section for the season. At any higher speed, it will be next to impossible for either the boat or the driver to stand the terrific punishment, the speaker said.

In the course of his address, Mr. Ditchburn traced the changing trend in speed-boat design during the last 25 years and showed two reels of motion-pictures of the development of speed-boat design and construction at Gravenhurst.

Dr. Hall, of the Ontario Research Foundation for the Automobile Standards Association, was introduced to the gathering of about 60 members of the Section who were present at the meeting, which was held at the Royal York Hotel on May 18. He spoke of the work of the Foundation in the direction of automotive research, particularly with respect to the testing of automobile-trim materials for fastness of colors.

Officers elected for the 1932-1933 Section year, as announced, are:

Chairman—Alexander N. Bentley, manager, Exide Batteries of Canada, Ltd.
Vice-Chairman—John L. Stewart
Secretary—Warren B. Hastings, manager, *Canadian Motorist*, re-elected
Treasurer—Marcus L. Brown, Jr., factory manager, Seiberling Rubber Co. of Canada, Ltd.

Retiring Chairman George W. Garner, who presided, reported that the Section stood in third place in percentage of quota in the Get-Your-Man campaign, having risen from sixth place since the April meeting. He expressed the hope that it would lead all the Sections when the Canadian Section reassembles next autumn.

The members voted to hold their usual summer golf meeting some time in July.

Ohio Student Branch Meets

THE S.A.E. Student Branch at Ohio State University held a meeting on May 13 to which members of the Society living in Columbus, Ohio, and the vicinity were invited. The forenoon was devoted to continuous demonstration of all equipment in the Engineering College, including automotive, aeronautic, electric and mechanical. From 1 to 8:30 p. m., demonstrations of the Cooperative Fuel-Research engine were given by K. T. Winslow, of the Waukesha Motor Co.

At a banquet at the Faculty Club, with John Younger, professor of industrial engineering at the university, acting as toastmaster, A. J. Scaife, of the White Motor Co. and President of the Society, was the speaker.

Officers of the Student Branch for next year were elected at a meeting on April 26, as follows:

Chairman—Henry P. Dudzin
Vice-Chairman—Charles Manney
Secretary and Treasurer—Don F. Marshall

Baltimore Section Aeronautic Meeting

THE curtain was lowered on Baltimore Section's meeting activities of the season with an unusually interesting aeronautic program at the Emerson Hotel on May 12. Nearly 100 persons were present to view the photographs displayed on the screen and motion-pictures of the giant airship Dornier Do-X, shown after the members' dinner, which was attended by 84 members and guests.

Aeronautics Chairman Charles Froesch introduced the two speakers, Commander Clarence H. Schildhauer and Frederick R. Neely, and conducted the evening's session. Commander Schildhauer spoke on the Aspects of Commercial Transatlantic Flying and told of the proposed routes that are most navigable at this time. Mr. Neely briefly outlined the activities of the Aeronautics Division of the Department of Commerce and presented many interesting points upon which he developed his theme on Commercial Air Transportation in the United States.

Section officers elected for 1932-1933 were:

Chairman—John A. White, branch manager, Mack-International Motor Truck Corp.
Vice-Chairman—Carlton A. Guenther, general manager, Jacobs Transfer Co.
Secretary—Espy W. H. Williams, statistician, Automotive Trades Alliance, re-elected.
Treasurer—Laurance F. Magness, president, Hercules Power Gasoline Co., re-elected.

Tire and Rubber Developments Reviewed at Cleveland

MEMBERS and guests of the Cleveland Section gathered in Akron, Ohio, on May 9 for a golf game at the Firestone Country Club, where the 30 players were guests of the club; a visit by 35 members to the main plant of the B. F. Goodrich Co.; a dinner in the office dining room of the Goodyear Tire & Rubber Co., attended by 160; and a technical session in the Goodyear Theater, as which 200 were present to hear and discuss three papers.

In the golf game, Joe Shea regained his crown as Section champion by making low gross score. At the Goodyear plant the manufacture of tires was observed and the visitors were especially interested in the conveyor systems and other production methods.

At the business meeting of the Section the result of the election of officers for next year was announced as follows:

Chairman—T. W. Kemble, Pennington Engineering Co.
Vice-Chairman—W. S. Howard, White Motor Co.
Secretary—W. G. Piwonka, Cleveland Railway Co.
Treasurer—T. R. Stenberg, Firestone Tire & Rubber Co.

Results of Rubber Research

Dr. J. W. Schade, director of research for the Goodrich company, presented the first paper, under the title, New Applications of Rubber from a Research Viewpoint. He cited numerous new uses of rubber that have been made possible by new knowledge of the properties of rubber and of various compounds with other ingredients. These include milking machines, rubber-lined containers for corrosive liquids such as muriatic acid, conveyor belts that withstand the deleterious effects of oxidation and decomposition at the high temperature of freshly quenched coke, and the combination of rubber with other materials such as metal, wood, textiles, glass and concrete.

While some of the properties of rubber are well known to those seeking a material to accomplish certain ends, a lack of adequate appreciation of the fact that compositions of definite properties are designed to suit particular

(*Concluded on p.* 26)

Personal Notes of the Members

Willys Resumes Willys-Overland Control

Feeling again the challenge to his well-known fighting spirit occasioned by present adverse industrial conditions, John N. Willys, after arranging with President Hoover to accept his resignation as United States Ambassador to Poland after completing his work sometime in June, was reelected chairman of the board of directors of the Willys-Overland Co., in Toledo, Ohio, and is again in active control of the affairs of the company, both through his reelection and his ownership of preferred stock. As in the past, he will concentrate his attention on the financial side of the business. At the stockholders' meeting on April 26, the directorate of 11 members was reelected and all officers were retained.

When Mr. Willys made his address at the Annual Dinner of the Society last January, those who knew the history of the man and sensed the feeling of nostalgia in his remarks, anticipated that no great time would elapse before he got into the economic fray in the automobile industry again. They remembered how, in the pioneer days of the industry, he bought the Toledo Automobile Co., then building the Toledo steam car, and on a "shoestring" organized the Willys-Overland Automobile Co. Also, the way in which he pulled the company through a crucial financial period during the depression period following the Armistice was recalled.

At the age of 17 Mr. Willys started his business career in a bicycle shop in Canandaigua, N. Y., his native town, in 1890, later moving the business to Elmira, N. Y., where he organized the Elmira Arms Co.

When the old Toledo Automobile Co. was about ready to pass out of the picture with the decline of the steam cars and the gasoline automobile was struggling for premier position against steam and electric vehicles, Mr. Willys took it over with a courage out of all proportion to his resources and in the course of years built up one of the largest enterprises in the automobile field.

From the time of his election to Associate membership in the Society in 1911, at which time he was president of the Willys-Overland Co., until 1930, he remained in active charge of the business. He was then elected chairman of the board of directors but resigned this position about a year ago, having been appointed Ambassador to Poland in March, 1930.

Cierva Awarded Guggenheim Medal

The Daniel Guggenheim gold medal for 1932 has been awarded to Juan de la Cierva for his development of the theory and practice of the Autogiro. The award was made by a board of eight members in the United States and seven foreign members, the countries represented being the United States, Canada, England, France, Germany, Holland, Italy and Japan.

The medal, established in 1928 by the Daniel Guggenheim Fund for the Promotion of Aeronautics, is sponsored jointly by the Society of Automotive Engineers and the American Society of Mechanical Engineers, each of which appoints four members of the board of award. Admiral H. I. Cone, Commissioner of the United States Shipping Board, was president of the 1931-1932 board which awarded the medal to Señor Cierva. At the recent annual meeting of the Fund, Capt. Emory S. Land, U.S.N., was elected president for 1932-1933, and Major E. E. Aldrin, of the aviation department of the Standard Oil Co., was elected vice-president. Admiral Cone, Captain Land and Major Aldrin are members of the S.A.E.

Medals have been awarded previously by the Fund to Orville Wright, Ludwig Prandtl of Germany and Frederick William Lanchester of England. Señor Cierva is a native of Spain.

Radford J. Berky is now serving the Chance Vought Corp., of East Hartford Conn., as draftsman. He was formerly connected in the same capacity with the Curtis Aeroplane & Motor Corp., in Buffalo.

Edward C. Blackman has been appointed sales engineer with the Koppers Products Co., of Kearny, N. J. Previously he was assistant manager of the service-station department of the Richfield Oil Corp. of New York.

Claude S. Cawthorn has joined the firm of Bennet & Elliott, Ltd., of Toronto, Canada, to promote the sale of garage and repairshop equipment and assist in shop problems. His former connection was with Cutten & Foster, also of Toronto, as equipment manager.

C. T. Coleman has relinquished his position as manager of the commercial-car division of the General Motors Export Co., of New York City, and is now an independent consulting engineer in Clarksburg, W. Va.

E. L. Cord, president of the Cord Corp., of Chicago, was elected a director of the Aviation Corp. of Delaware at the annual meeting of stockholders in Wilmington on April 29. Nineteen directors were relected for terms of three years.

Thomas H. Corpe, who has been directing special advertising work in Canada for the Fisher Body Corp., has been appointed advertising manager of General Motors Products of Canada, Ltd., at Oshawa, Ont.

Howard Dingle, president of the Cleveland Worm & Gear Co., has been elected president of the Farval Corp., of Cleveland, which was formed recently for the manufacture and sale of the Farval centralized system of lubrication formerly manufactured by Lubrication Devices, Inc., of Battle Creek, Mich., the rights to which have been acquired by the new company.

Nicholas Dreystadt has been advanced from the position of parts and service manager of the Cadillac Motor Car Co., of Detroit, to that of works manager.

Alvin H. Gossard, who was vice-president in charge of automotive and other transportation of the Middle West Utilities Co., of Chicago, is now superintendent of delivery and transportation of the Southern United Ice Co., of Jackson, Miss.

George A. Green has been advanced from the position of vice-president in charge of engineering of the General Motors Trucks Co., of Pontiac, Mich., to that of vice-president in charge of operations. Besides having charge of manufacturing operations, he will remain in charge of engineering work of the company.

R. E. W. Harrison has resigned as sales engineering director of the **Cincinnati Milling Machine & Cincinnati Grinders, Inc.** He had been with the Cincinnati Milling Machine Co. since 1926, at which time he joined the organization as chief engineer and director of Cincinnati Grinders, Inc. Mr. Harrison's second year in office as Chairman of the Cincinnati Section of the American Society of Mechanical Engineers has just terminated but he will continue as Secretary-member of the Executive Committee of the Machine-Shop Practice Division of the A.S.M.E., and his other activities in connection with engineering standardization projects will be continued.

R. R. Higginbotham has formed a connection with the Chance Vought Corp., of East Hartford, Conn., as aeronautic engineer. His previous connection was with the Stearman Aircraft Co., of Wichita, Kan., as project engineer.

Edward H. Kocher, formerly treasurer and general manager of the Bijur Lubricating Corp., of Long Island City, N. Y., was recently elected president and general manager of the corporation. He had been associated with the late Joseph Bijur in all of his business enterprises for the last 26 years.

John G. Lee, who was project engineer with the American Airplane & Engine Corp., of Farmingdale, N. Y., is now associated in the same capacity with the Chance Vought Corp., of East Hartford, Conn.

W. Laurence Le Page, vice-president of the Kellett Aircraft Corp., of Philadelphia, and Chairman of the Philadelphia Section, was recently appointed by the Franklin Institute of Pennsylvania as a member of its committee on sciences and art. The function of the committee is to recommend persons

(*Concluded on p. 44*)

News of the Sections

(*Concluded from p. 24*)

kinds of service still exists. Knowledge of what is desired and how to select the best compositions and combine them with other materials should point the way to wider applications, said Dr. Schade. Often the required knowledge is not available, and then careful research is necessary and experimental work must be planned and executed to yield data on which further progress can safely be based. Systematic study has been extremely fruitful in improvement of quality, and, as the investigations are extended, new and broader fields of usefulness of rubber will be found. The rubber manufacturer, however, needs to know the particular requirements of inventors, designers and engineers who want to accomplish specific results that rubber may produce.

Tire Rims and Air Wheels

A large display of wheels and rims, from the early quick-detachable rims to present 13-in. drop-center rims with continuous removable side rings that "button" on and off by a ring-well made on the principle of the drop center for the tire, was shown and demonstrated by W. S. Brink, development engineer of the Firestone Steel Products Co. In a paper on the subject, Mr. Brink spoke of the rim and tire standards of the Tire & Rim Association of America and the control exercised over them by the association through inspectors in the plant of each rim and wheel manufacturing company.

Rhys D. Evans, research technologist of the Goodyear company, gave a talk on air wheels, accompanied with lantern slides showing the relative cross-sections, bearing areas, air pressures and load capacities of these tires and balloon tires. Slow-motion pictures of doughnut tires under laboratory test against a large flywheel were also shown. A reel of motion-pictures showed the use of air wheels on trucks in citrus-fruit groves and in heavy going in mud and at airports.

Stainless-Steel Welding Discussed at Philadelphia

INFORMAL discussion of the use of drawn stainless-steel structures by correct welding was presented at the May 11 meeting of the Philadelphia Section by Frank H. Russell and E. J. W. Ragsdale, of the Edward G. Budd Mfg. Co. The talks were illustrated with motion pictures of the various processes described, and at their conclusion questions and comments were offered from the floor, those taking leading parts being R. W. A. Brewer, consulting engineer; Charles O. Guernsey, of the J. G. Brill Co.; Joseph Geschelin, of *Automotive Industries;* and J. P. Stewart, of the Vacuum Oil Co.

As a special-feature attraction for the members, invitations were extended at the meeting for them to ride in the new Budd-Michelin pneumatic-tired rail-car built of shot-welded stainless steel.

The meeting was attended by 153 members and guests, of whom 52 were present at the dinner and entertainment preceding the technical session. At a business meeting, Chairman W. Laurence LePage announced the election of officers of the Section for next year as follows:

Chairman—J. P. Stewart, Vacuum Oil Co.
Vice-Chairman—O. M. Thornton, Titeflex Metal Hose Co.
Secretary—J. B. Franks, Jr., The White Co.
Treasurer, J. C. Geniesse, Atlantic Refining Co.

Papers on Motorboat Powerplants Given at Seattle

TOPICS relating to motorboat powerplants were presented by three speakers at the closing meeting of the Northwest Section, held at Seattle on May 13. Officers for the coming year were elected and installed, Charles Finn succeeding C. H. Bolin as Chairman. Others elected were: Sherman Bushnell, Vice-Chairman; A. W. Oberg, Treasurer; and James H. Frink, Secretary.

Charman Bolin thanked the members for their support and attendance during the season just past, saying that the success of any association depends upon the interest shown by the members and that good progress had been made by the Section in the last year. Reece Lloyd, Chairman of the Membership Committee, reported the Get-Your-Man drive as nearing its quota for the Northwest Section.

Discussion of a joint summer meeting with the Oregon Section, to be held about the middle of June, in Vancouver, B. C., was followed by a motion to lay further plans with that end in view.

The program of the May meeting consisted of three papers of special interest to engineers of the "water-bejewelled" Puget Sound region, as follows: The Relation of Power to Boat, by George Draper, marine engineer with the Pacific Marine Supply Co.; Fundamentals of Marine-Engine Construction, by J. L. Patton, manager of the Seattle Marine Equipment Co.; and Powerplant Conversion for Racing Purposes, by Glenn Shaw, manager of Shaw & Mercill and a racing-motorboat builder and driver.

Puget Sound Diesel-Engine Field

Mr. Draper discussed the general requirements of various types of boat, both gasoline and Diesel powered, from the outboards to the large commercial craft. He pointed out that 6000 fishing boats are used in the Puget Sound region and each presents its own particular problems as regards correct engine power. A market is at hand, he said, for a small two-cylinder four-cycle Diesel engine of about 20 hp. for craft of about 36 ft. overall. The large halibut boats that make the trip to Kodiak Island, Alaska, and back in 20 or 21 days, require massive engines, as they are always under steady power, and reliability and power are more to be considered than weight. The Diesel engine is also preferred for large motor yachts because of the low cost of operation and reduction of fire hazard, while weight is not an important consideration.

Mr. Patton dealt with marine-engine designs and detailed construction, making minute comparisons with automobile and truck powerplants. He said that the Diesel engine is coming to the front even in the yacht field, while the gasoline engine is supreme in craft smaller than 50-footers. High-output generators are desired to develop the needed quantity of current.

Converted Automobile Engines Satisfactory

Conversions of automobile engines for marine use were found satisfactory in some jobs, and many good converted engines are in use, continued Mr. Patton, but the original engine must be a good one. Adequate provisions for reduction gears, cooling systems adapted to get results and manifold cooling are necessary. Full-load operation makes heavier demands in marine work than in automotive work.

Mr. Shaw related his experiences in converting automobile engines for motorboat racing, in the 151-cu-in. class. His own boat, which won many events, was driven by a Star engine that he had changed in practically every detail to develop speed. Weight had to be cut down to 250 lb. and other changes made to increase the output to 85 hp. at more than 4200 r.p.m. Balancing of the recriprocating parts helped greatly in getting better performance. His boat in the 151 cu-in. class has attained a speed of 52 m.p.h. in competition.

Lively discussion followed presentation of the three papers and brought out, among other points, that danger of explosions due to gas vapors gathering in the bilge can be avoided only through the provision of ventilation systems, which are very important.

"Met" Marine Division Meets

THE first meeting of the new Marine Division of the Metropolitan Section was held on May 24 at the Park Central Hotel, New York City. The main subject was the elimination of fire hazards aboard motorboats through the installation of internal-combustion engines burning low-volatile fuels.

Three papers on the program were: Fuelizer Survey, by J. C. McCormack, vice-president of Godward Gas Generator, Inc.; Fuel Oil Is the Fuel for Marine Engines, by Alfred Schwartz, consulting engineer of the Fuel Oil Motor Corp.; and Fireproof Motorboats with Foolproof Diesel Engines, by Julius Kuttner, consulting engineer.

Applicants for Membership

The applications for membership received between April 15 and May 14, 1932, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, J. A., superintendent of equipment, Missouri State Highway Department, *Jefferson City, Mo.*

BAGLEY, THOMAS J., chief chemist, R. M. Hollingshead Co., *Camden, N. J.*

BARKER, BEN H., commercial zoneman, Ford Motor Co., *Seattle.*

BETANCOURT, GILBERT, designer, Hudson Motor Car Co., *Detroit.*

BOERLAGE, G. D., director proefstation Delft, Bataafsche Petroleum Maatschappy den Haag, *Delft, Holland.*

CLAIR, GEORGE P., JR., sales manager, United Wheel & Rim Service, Inc., *Philadelphia.*

CARY, BEECHER BANCROFT, research engineer, Automotive Fan & Bearing Co., *Jackson, Mich.*

COLEMAN, LEROY A., assistant works manager, Edward G. Budd Mfg. Co., *Detroit.*

CROWDER, RAYMOND, assistant district sales manager, Gulf Refining Co., *Philadelphia.*

CROWELL, ABRAHAM ALBERT, design draftsman, Naval Aircraft Factory, *Philadelphia.*

ENRIGHT, JACKSON, zone manager, General Motors Truck Co., *Newark, N. J.*

FISCHER, HANS, research engineer, Falk Corp., *Milwaukee.*

GIBSON, HAROLD J., research engineer, Ethyl Gasoline Corp., *Detroit.*

GONNASON, RAY, co-owner, Gonnason Bros., *Kent, Wash.*

HACKER, OSCAR H., chief engineer, Austro Daimler-Puch-Werke A. G. Werk Wiener Neustadt, *Vienna, Austria.*

HOLLISTER, K. L., engineer, The Texas Co., *New York City.*

KEVERS, NORMAN R., sales engineer, Aluminum Colors, Inc., *Indianapolis.*

KNIERIEM, WARREN G., draftsman, Naval Aircraft Factory, *Philadelphia.*

KREITZMANN, ORVILLE E., chief engineer, Wisconsin Knife Works, Beloit, Wis.

LAKEVOLD, HENRY JULIUS, automobile mechanic, Los Angeles County Department of Recreation and Playgrounds, *Los Angeles.*

LARSON, GUSTAF, vice-president, chief engineer, Aktiebolaget Volvo, *Gothenburg, Sweden.*

LEANDER, CHRISTIAN T., service manager, Mack Motor Truck Co., *Allston, Boston.*

MAAG, GEORGE ALBERT, 3207 Natchez Avenue, Cleveland.

MARION, FRANK IVICHIEVICH, lubrication engineer, Gulf Refining Co., *Toledo.*

MARTIN, EDWARD ALFRED, draftsman, Lincoln body engineering division, Ford Motor Co., *Dearborn, Mich.*

MCCALLUM, THOMAS W., service manager, J. B. Ross, Ltd., *Hamilton, Ont., Canada.*

MCGRATH, JOSEPH, garage superintendent, Freihofer Baking Co., *Philadelphia.*

MCMILLIN, ROBERT MILTON, laboratory assistant, experimental laboratory, Chevrolet Motor Co., *Detroit.*

MCVEIGH, JOHN ROSS, draftsman, Continental Motors Corp., *Detroit.*

MINSHALL, E. MORTON, service department, Autocar Co., *Ardmore, Pa.*

MYRIN, LARS B., automotive efficiency engineer, Sun Oil Co., *Philadelphia.*

NUTTILA, M. E., superintendent of motor-vehicles, Crew-Levick Co., *Philadelphia.*

PAXTON, HUGH M., engineer and Michigan and Ohio representative, Dardelet Threadlock Corp., *New York City.*

PONTREMOLI, JEAN, chief engineer, Société des Moteurs Gnome et Rhone, *Paris.*

POWELSON, WILLIAM H., service engineer, J. G. Brill Co., *Philadelphia.*

QUARTULLO, O. F., president, Maccar Pittsburgh Truck Corp., *Scranton, Pa.*

RAMSEY, CLELL C., maintenance helper, Van de Kamp's Holland Dutch Bakers, Inc., *Seattle.*

READING, HUGH A., writer, Roche Advertising Co., *Chicago.*

ROESING, W. H., field representative, Champion Spark Plug Co., *Toledo.*

ROSEBROOK, G. L., architect, member of the service-station managers' committee, Standard Oil Co. of New Jersey, *New York City.*

RUSSELL, JAMES, master artificer, Royal Canadian Ordnance Corps., *Winnipeg, Man., Canada.*

RUSSO, JOSEPH E., consultant and engineer, E. F. Chaskel, *Indianapolis.*

THORNBERG, BERT C., fleet mechanic, Consolidated Freight Lines, *Seattle.*

TSUBOTA, SHUKICHI, bachelor of engineering, Showa Seisakusho Tsutsumikata, Ikegami-Machi, *Tokio-Fu, Japan.*

ULRICH, BENJAMIN C., service manager, Eaton Mfg. Co., *Philadelphia.*

VINCENT, EDWARD T., Diesel research engineer, Continental Motors Corp., *Detroit.*

SNIVELY, RICHARD K., advertising writer, N. W. Ayer & Son, *Philadelphia.*

SORACIO, C., president, Soracio Corp., *Harrisburg, Pa.*

STEARNS, WALTER VINCENT, petroleum research engineer, Sun Oil Co., *Marcus Hook, Pa.*

STERHARDT, JAMES A., draftsman, Seversy Aircraft, *College Point, N. Y.*

SWEENEY, LEWIS J., sales engineer, E. P. Rotzell Co., *Philadelphia.*

SYDNOR, F. H., Crosby Lighterage Co., *Seattle.*

WATSON, DONALD REED, draftsman, Naval Aircraft Factory, *Philadelphia.*

WEINFIELD, JOSEPH, president, Frame & Axle Alignment of New England, *Boston.*

WEYL, GEORGE J., draftsman, Chevrolet Motor Co., *Detroit.*

WHITE, R. L., sales engineer, Climax Machinery Co., *Indianapolis.*

WILLIAMS, CAPT. LAURIN L., U. S. A., *Fort Benning, Ga.*

Howard E. Maynard

AS the result of a paralytic stroke, Howard E. Maynard, assistant chief engineer of the Chrysler Corp., passed away suddenly at his residence in Detroit on May 12. His death is greatly deplored by many friends and acquaintances of long standing in the automobile industry, with which Mr. Maynard had been identified for nearly a quarter of a century.

Born at Amherst, Mass., in 1879 and technically educated at the Massachusetts State College and the Worcester Polytechnic Institute, from the latter of which he was graduated in 1901 with the degree of Bachelor of Science in Electrical Engineering, Mr. Maynard entered the automobile industry in 1910 as assistant engineer with the United States Motor Co., in Detroit. The following two years he served as chief engineer of the Lion Motor Car Co., of Adrian, Mich. In 1913, as production engineer, he was placed in full charge of production for the Maxwell Motor Co., of Detroit. By 1921 he had been advanced to the position of assistant executive engineer of the company, and after the taking over of the Maxwell company by the Chrysler Corp., he was appointed assistant chief engineer of the latter organization, which position he retained until his death.

Mr. Maynard was admitted to Member grade in the Society in April, 1920, and became a member of the Detroit Section. This year he was serving as a member-at-large on the Sectional Committee on Plain and Lock Washers and as a member of the Subcommittee No. 2 on Lock Washers of the Sectional Committee.

George H. Hannum

AFTER a career of quarter of a century in the automotive industry, George H. Hannum passed away at Philadelphia in April. Mr. Hannum was general manager of the G. M. Heintz Mfg. Co., of that city, a position which he assumed last year.

Born at Thorndale, Pa., in January, 1877, Mr. Hannum studied special courses in mechanical drawing, designing and mechanical engineering after receiving his public-school education and started on his career in the automobile industry in 1907 with the Autocar Co., of Ardmore, Pa., as chief inspector. From 1908 to 1912 he was superintendent in charge of manufacturing for the Detroit Lubricator Co. For the following eight years he was general manager of the Saginaw Products Co., of Saginaw, Mich. In 1920 he was elected president and general manager of the Oakland Motor Car Co., of Pontiac, Mich., a position he filled until about 1926, when he was elected president and general manager of the Hannum Mfg. Co., of Milwaukee, a company that he organized in 1925 for the manufacture of heavy-duty steering-gears. Following the sale of the latter company in 1930, Mr. Hannum joined the Heintz Mfg. Co. in 1931.

Mr. Hannum was elected to Member grade in the Society in January, 1923, and had been a member of the Detroit, Milwaukee and Philadelphia Sections.

Notes and Reviews

AIRCRAFT

Safety Devices in Wings of Birds. By R. R. Graham. Published in *The Journal of the Royal Aeronautical Society*, January, 1932, p. 24. [A-1]

The connections between the ways of birds in the air, their size, the shape and loading of their wings, the presence or absence of slots, and, when present, their development, are so intricate that many years of investigation would be required before really satisfactory conclusions could be reached, the author contends, and he states that only the surface of the subject has been scratched in his paper. He expresses the hope, however, that it will indicate the amazing width of this field for research and the possibility of the riches that may be found in it.

The observations, theories and tentative conclusions discussed in the paper are summarized at the end, and a list of a considerable number of birds whose flight characteristics have been studied is included. An appendix offers corrections to this tabulation, based on further work since the presentation of the paper in 1930, and a second appendix is devoted to a detailed study of a Montagu's Harrier from an action photograph.

General Formulas and Charts for the Calculation of Airplane Performance. By W. Bailey Oswald. N.A.C.A. Report No. 408, 1932; 50 pp., with tables and charts. Price, 25 cents. [A-1]

Theory of Wing Sections of Arbitrary Shape. By Theodore Theodorsen. N.A.C.A. Report No. 411, 1931; 13 pp., with tables and charts. Price, 10 cents. [A-1]

Preliminary Investigation of Modifications to Conventional Airplanes To Give Non-Stalling and Short-Landing Characteristics. By Fred E. Weick. N.A.C.A. Report No. 418, 1932; 16 pp., illustrated. Price, 5 cents. [A-1]

Preliminary Investigation of Rolling Moments Obtained with Spoilers on Both Slotted and Plain Wings. By Fred E. Weick and Carl J. Wenzinger. N.A.C.A. Technical Note No. 415, April, 1932; 11 pp., 15 figs. [A-1]

Characteristics of Two Sharp-Nosed Airfoils Having Reduced Spinning Tendencies. By Eastman N. Jacobs. N.A.C.A. Technical Note No. 416, April, 1932; 5 pp., 10 figs. [A-1]

Development of Tailless and All-Wing Gliders and Airplanes. By Robert W. E. Lademann. Translated from *Die Luftwacht*, February, 1932. N.A.C.A. Technical Memorandum No. 666, April, 1932; 12 pp., 3 figs. [A-1]

Application of the Theory of Free Jets. By A. Betz and E. Petersohn. Translated from *Ingenieur-Archiv*, May, 1931. N.A.C.A. Technical Memorandum No. 667, April, 1932; 25 pp., 32 figs. [A-1]

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H. Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

Ergebnisse des 12. Rhön-Segelflug-Wettbewerbes 1931. By Walter Georgii. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 29, p. 97, and March 14, 1932, p. 125. [A-1]

The 12th annual sailing-flight competition in Germany is characterized as a fitting climax to a year of extraordinary achievement in the field of motorless aviation. Some of the year's noteworthy events were the flights made in all parts of Germany for the prize for the best performance of the year; the competition for the Hindenburg prize; the common introduction of towed starting of gliders, so that motorless flights might be made from any airport; and the flights made in the Swiss Alps.

A strong evidence of the progress of motorless aviation was the fact that the competition did not include any gliding events, being solely devoted to sailing flights. The applicants for participation in the competition numbered 59, and 49 sailing craft took part.

The winner of the flight-duration event in the advanced training class did not equal the 1930 record, because of weather conditions, but balancing this unfavorable showing is the large number of flights, 300, as compared with 132 of the preceding year. The long-distance record was made with a flight of 137 miles, and the highest altitude reached was 2267 ft.

Of especial interest were the flights utilizing pressure conditions caused by air-temperature variations and those made during a thunder-storm, showing the fliers to be "masters of wind, cloud and unfavorable weather."

Die Aufgaben der Elektrotechnik in der Luftfahrt. By Heinrich Fassbender. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 14, 1932, p. 135. [A-1]

A short summary covering the varied tasks of electricity in aviation is given. For the most part only main points are touched on; details, however, being included for the most outstanding developments. A bibliography including 20 references enables the reader to pursue a more exhaustive study of the subject.

Among the topics referred to are measuring technique; brakes for power measurement; aircraft instrument panels; ignition, especially shielding from radio interference; starting; lighting; production of electric current; communication, including telephones within the aircraft and radio for land communication; navigation aids; landing aids; noise measurement and distance measurement.

Die Zunahme des Maximalauftriebes von Tragflügeln bei Plötzlicher Anstellwinkelvergrösserung (Böeneffekt). By Max Kramer. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, April 14, 1932, p. 185. [A-1]

A report is given of wind-tunnel tests in which wing models were subjected to sudden increases in angle of attack, analogous to the effect of vertical gusts, and the resulting forces measured. The results tend to show that the maximum-lift values increase with the rapidity of change of angle of attack. This conclusion is stated to be of special significance in calculating the stresses produced by gusts in aircraft of low wing-loading. The results of such calculations for a high-efficiency seaplane and a sport-type aircraft are presented.

Vereinfachtes Verfahren zur Berechnung der Flugleistungen von Landflugzeugan. By Gustav Förstner. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 29, 1932, p. 169. [A-1]

The object of this article is to render less difficult the correction of flight test data for wind and air-density effects. The commonly used formulas are simplified and graphs developed. The article is a report of the German institute for aeronautical research.

Der Boden-Effekt beim Fluge in Erdnähe. By E. Tönnies. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 29, 1932, p. 157. [A-1]

While previous investigations of ground effect have been concentrated on the change in drag, an increase in lift too considerable to be neglected is also part of the phenomenon. This is the thesis of the present article, in which the author sets forth the formulas for calculating take-off runs and compares the data obtained from them with those actually observed, reports model and flight tests made by the aviation bureau of the Hannover engineering college to show the increase in lift with the nearness of the ground, sets forth a theory of the influence of

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Notes and Reviews

Continued

ground effect in starting and landing and compares the conclusions drawn from this with experimental data.

The Aircraft Year Book for 1932. Compiled by the Aeronautical Chamber of Commerce of America, Inc. Published by D. Van Nostrand & Co., Inc., New York City, 1932; 626 pp., including index. **[A-3]**

The Year Book of the A. C. C. A., which has become an indispensable tool to the aircraft industry and its related interests, is now available in its 14th edition. The material in it has been reorganized into five principal divisions: Part I, The Year in the Air, covering in the usual brief way the history of the year's developments and predictions for 1932, and including a résumé of Army and Navy activities, airship development, notable flights and the growth of commercial air-transport; Part II, Manufacturing and Engineering Progress; Part III, Aviation Chronology and Records, a day-to-day account of important happenings; Part IV, Flying Facts and Figures; and Part V, Aeronautical Directory and Trade Index.

Among notable additions in this volume are: the chapter devoted entirely to the Autogiro, a chapter on the perfecting of component parts for aircraft and a comprehensive report of airport construction and operation.

It is interesting to find that air transport experienced the greatest year in its history in 1931, and, in spite of the general business decline, showed substantial gains in the number of plane-miles and passenger-miles flown, the total number of passengers carried, the volume of mail transported and the weight of express matter carried by airplane.

Aerial and Marine Navigation Tables. By John E. Gingrich. Published by the McGraw-Hill Book Co., Inc., New York City and London, 1931; 63 pp. **[A-4]**

The simplified tables for the quick solution of aerial and marine navigation problems contained in this volume are a rearrangement of the tables devised by Dr. Ogura, hydrographic engineer of the Japanese Navy. The altitude part of the tables is similar in conception to tables published many years ago by the French mathematician, Souleguet. The azimuth is calculated in a manner similar in conception to that used by Captain Lecky in his famous ABC tables.

The tables are reported to have been thoroughly tested in the air and at sea and to have been found accurate and rapid and simple to use. They are planned for use with either sea horizon or bubble sextant and include necessary tables of corrections.

The same method is used in all sights and involves only the use of simple addition and subtraction in making computations. The range is wide.

The German Investigation of the Accident at Meopham (England). By Hermann Blenk, Heinrich Hertel and Karl Thalau. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 15, 1932. N. A. C. A. Technical Memorandum No. 669, April, 1932; 30 pp., 26 figs. **[A-4]**

The Triangle Parachute. By Major E. L. Hoffman, U. S. A. Published in *Aviation Engineering*, January, 1932, p. 27. **[A-4]**

The discussion in this article is limited to the parachute canopy, per se, and particularly to a description of the triangle type originated by Major Hoffman.

The conditions to be met by a canopy as outlined by the author, are: lift, promptness of opening, certainty of opening, strength, non-oscillation and steerability. These characteristics are considered with special reference to the triangular parachute, and the author points out that, while heretofore all parachutes were designed to descend vertically, the Triangle, in descending, travels along an inclined plane and has an inherent horizontal speed of about 3 m.p.h. With regard to its steerability, the author explains that it moves away from the tail over one shoulder and can be turned at will to right or left by pulling on the risers over the other shoulder.

Atterrissage sur Engin Mobile et Lancement par Catapulte. By Camille Rougeron. Published in *L'Aéronautique*, March, 1932, p. 67. **[A-4]**

The suggestion is made that the experience gained in refueling in flight and in aircraft-carrier landing and launching of aircraft be put to work in the interests of commercial aviation. The author describes mobile units equipped with braking means that would sensibly shorten the landing run of airplanes and also means for catapulting aircraft that would be acceptable in passenger-carry-

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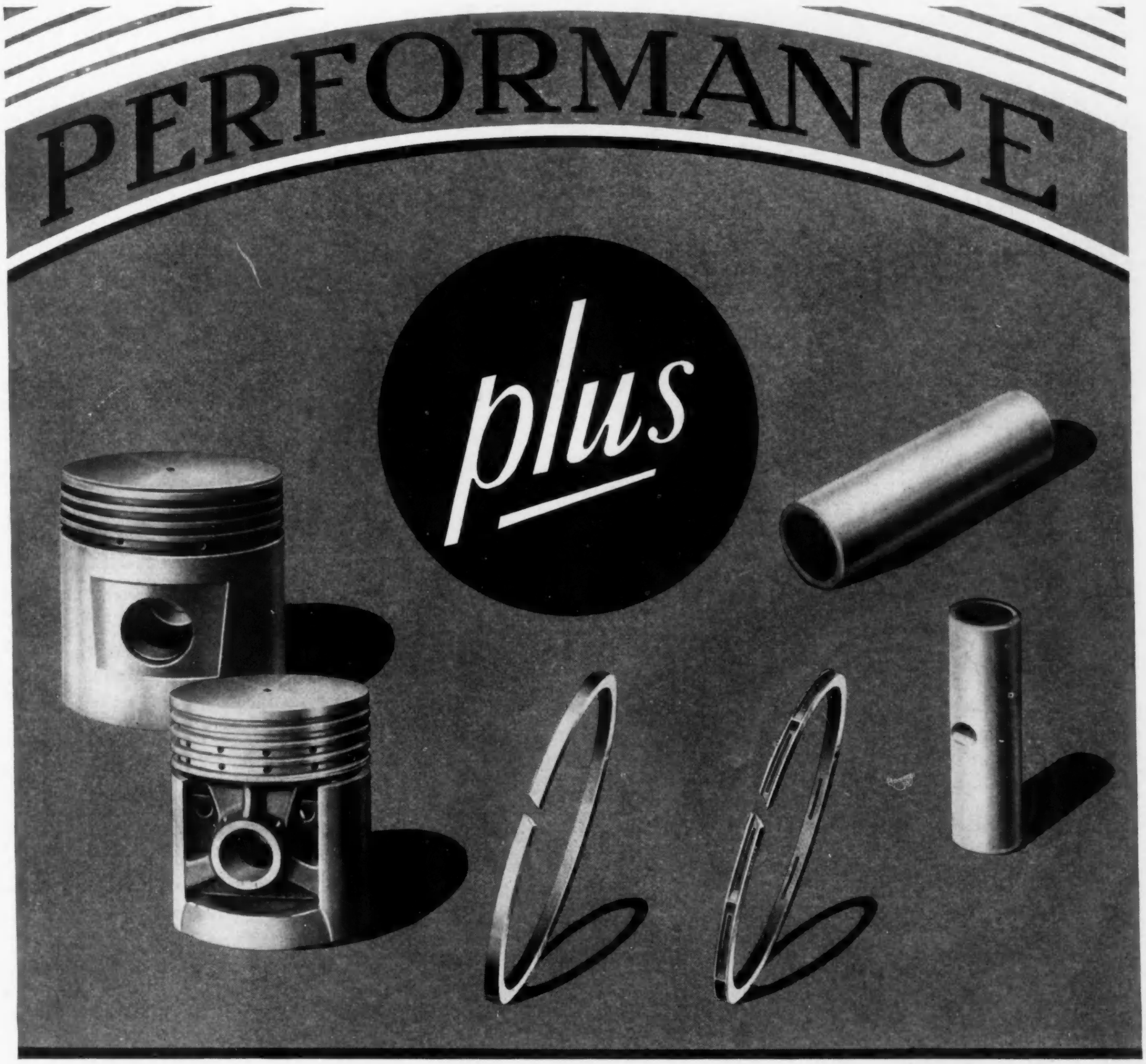

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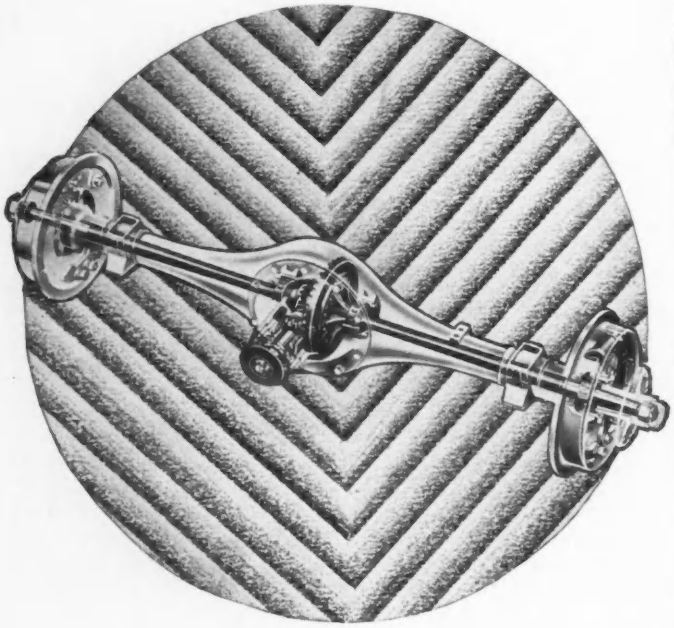

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Notes and Reviews

Continued

ing air transports. The limitations imposed on the shortening of landing and launching runs by considerations of passenger comfort are pointed out, as is also the probable effect on aircraft design and landing-field development of the adoption of such means of starting and stopping flight.

CHASSIS PARTS

A Consideration of Power Braking in Its Application to Passenger Cars. By Howard K. Gandelot. Published in *Automotive Daily News*, Feb. 23, 24 and 25, 1932. **[C-1]**

Increased speed, heavier cars, an increase in the number of women drivers, a larger volume of traffic and the general advent of free-wheeling are cited as contributing factors to the need for improved braking systems that afford effective braking action with the minimum of physical effort on the pedal. The principles of design and operation of the available types of power brake, that is, electric, air, oil, vacuum and mechanical, are outlined and special consideration is given to the Stewart-Warner system of direct-acting mechanical power brakes.

La Roue Libre et l'Automobile. By Maurice Sainturat. Published in *Journal de la Société des Ingénieurs de l'Automobile*, March, 1932, p. 1682. **[C-1]**

Free-wheeling is here to stay, in the opinion of the author. None of the faults found in free-wheeling vehicles can be attributed to the free-wheeling device itself, he asserts, but they arise from the operation of other elements, the defects in which can easily be remedied.

The failure to develop free-wheeling after its introduction 12 years ago was due, in the author's opinion, to lack of public demand, and its recent sudden popularization, especially in this Country, was the natural outgrowth of a buyers' market. The theory of free-wheel operation is outlined, design principles are set forth and design details of specific commercial devices are described.

Messungen des Forschungsinstituts für Kraftfahrwesen und Fahrzeugmotoren an der Technischen Hochschule Stuttgart mittels des Tel-Geräts bei Versuchsfahrten mit Freilaufgetriebe der Zahnradfabrik A.-G. Friedrichshafen auf dem Nürburgring. By E. Speigel. Published in *Automobiltechnische Zeitschrift*, April 25, 1932, p. 200. **[C-1]**

An account is given in this article of the instruments, test methods and results of an investigation of the effects of free-wheeling on fuel consumption and general automobile operation. The automotive research bureau of the Stuttgart engineering college conducted the tests. Phases of automobile operation covered were coasting on a level road, deceleration, speed and negotiating down-grades.

Untersuchungen an Blattfedern. By H. Stark. Published in *Automobiltechnische Zeitschrift*, March 25, 1932, p. 151. **[C-1]**

The spring committees of the German engineering society and the German society for steel treating are engaged in a cooperative research, the object of which is to develop an exhaustive guide for reliable spring design in such form as to be readily usable by the practical engineer. The present article is an abstract of a progress report on this work. Seven conditions characteristic of actual operation that customary spring calculations fail to take into account are enumerated and tests to determine the effects of a few of these factors are recounted. Future work will deal with spring vibration.

ENGINES

High-Speed Diesel Engines. By P. M. Heldt. Published by the author, Chestnut and 56th Streets, Philadelphia, 1932; 312 pp. **[E-1]**

Mr. Heldt needs no introduction to readers of automotive literature. In this latest work, he presents a condensed, orderly review of some of the research work that has been done both here and abroad on problems connected with various phases of design of the high-speed or automotive oil engine, together with descriptive data and illustrations of typical examples of the various sub-classes that have actually been built.

Much of the widely scattered published material, including data previously available only in foreign languages, has been brought together in this volume, and the author states that the primary purpose of the book is "to help those who are engaged in design and experimental development of these engines, as well as the pioneer operators of vehicles equipped with them."

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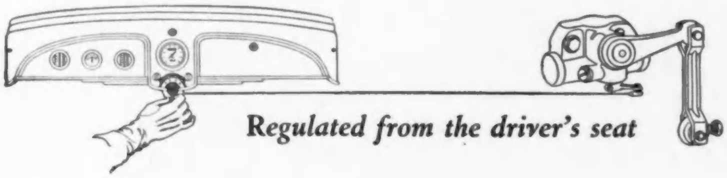

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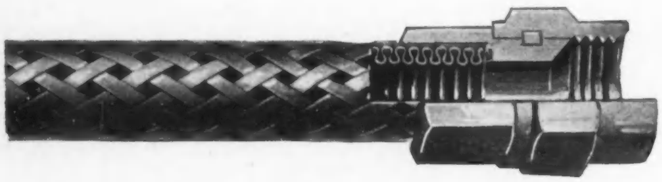

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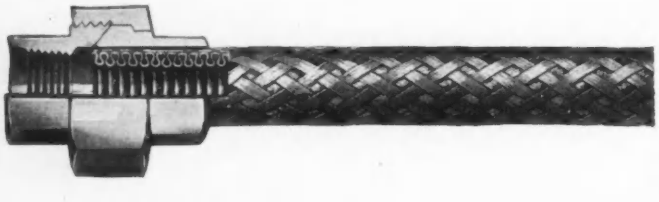

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Notes and Reviews

Continued

Dynamics of Engine and Shaft. By Ralph E. Root. Published by John Wiley & Sons, Inc., New York City and London, 1932; 184 pp. **[E-1]**

The author presents methods for evaluating the forces that operate in a reciprocating engine, traces their effects in turning moment on the shaft and in bearing pressures and, by emphasis on the periodic character of forces, reveals their significance in relation to vibrations. To this latter end, the work includes a treatment of torsional and transverse vibrations of elastic systems and a discussion of critical speeds.

In the first seven chapters, dealing with balance, turning moment and bearing pressures, the mathematical and mechanical principles are such as should be included in elementary calculus and engineering mechanics. In the last three chapters, dealing with vibrations, use is made of linear differential equations, both ordinary and partial, and of the theory of elasticity.

The work is intended primarily as a textbook and is a direct result of the author's experience in presenting the subject matter to student officers in the Postgraduate School of the United States Naval Academy during the last 12 years.

Positioning of Link-Rod Wristpins in Articulated Connecting-Rods. By Glenn D. Angle. Published in *Aviation Engineering*, January, 1932, p. 11. **[E-1]**

Among the methods that may be employed in connecting two or more rods to a single crankpin of an engine, according to the author, are: the forked or straddle type, the slipper type and the articulated type, the last named apparently being the least understood.

Mr. Angle explains that there are combinations of elements, whether it be the number of rods to be accommodated, the existing loads, or both, where the only safe connecting-rod construction that can be used is the articulated form. He emphasizes that attempts to employ the forked or slipper types under such circumstances indicate an element of fear or lack of knowledge on the part of the designer relative to the kinematics of the articulated connecting-rod movements.

In this article he briefly discusses certain phases of these motions in a simple manner with a view toward clarifying the work of the designer. The discussion is especially directed toward the location of the link-rod wristpins as it affects the length of stroke and the compression ratio.

The Effect on Airplane Performance of the Factors That Must Be Considered in Applying Low-Drag Cowling to Radial Engines. By William H. McAvoy, Oscar W. Schey and Alfred W. Young. N. A. C. A. Report No. 414, 1932; 19 pp., illustrated. Price 20 cents. **[E-1]**

Considerations of Air Flow in Combustion Chambers of High-Speed Compression-Ignition Engines. By J. A. Spanogle and C. S. Moore. N. A. C. A. Technical Note No. 414, April, 1932; 10 pp., 5 figs. **[E-1]**

Praktische Drehschwingungs-Untersuchung von Luftfahrzeug-Triebwerken. By Karl Lürenbaum. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 29, 1932, p. 105. **[E-1]**

Of utmost importance in judging the reliability of an aircraft engine is the knowledge of its vibration characteristics and the stresses resulting from these vibrations. A first step in vibration research is the theoretical calculation, the method for which is outlined. Such calculations make possible the avoidance of design errors and the understanding of the behavior of the completed engine.

To secure the knowledge of vibration characteristics of the engine in operation, measuring instruments are necessary. Two of these, developed by the German institute for aeronautical research, are described. The first, the torsiograph, is attached to the free end of a crankshaft and is suitable for the investigation of aircraft engines with direct and rigidly coupled propellers. For engines with intermediate shafts, couplings and gears, an instrument of a different type is needed, and this is provided in a torsion indicator.

Results obtained with the second type of instrument on a geared aircraft engine, to show how the actual vibration and consequent stresses differ from calculated predictions, are presented. Further vibration measurements made by the German institute for aeronautical research are reproduced.

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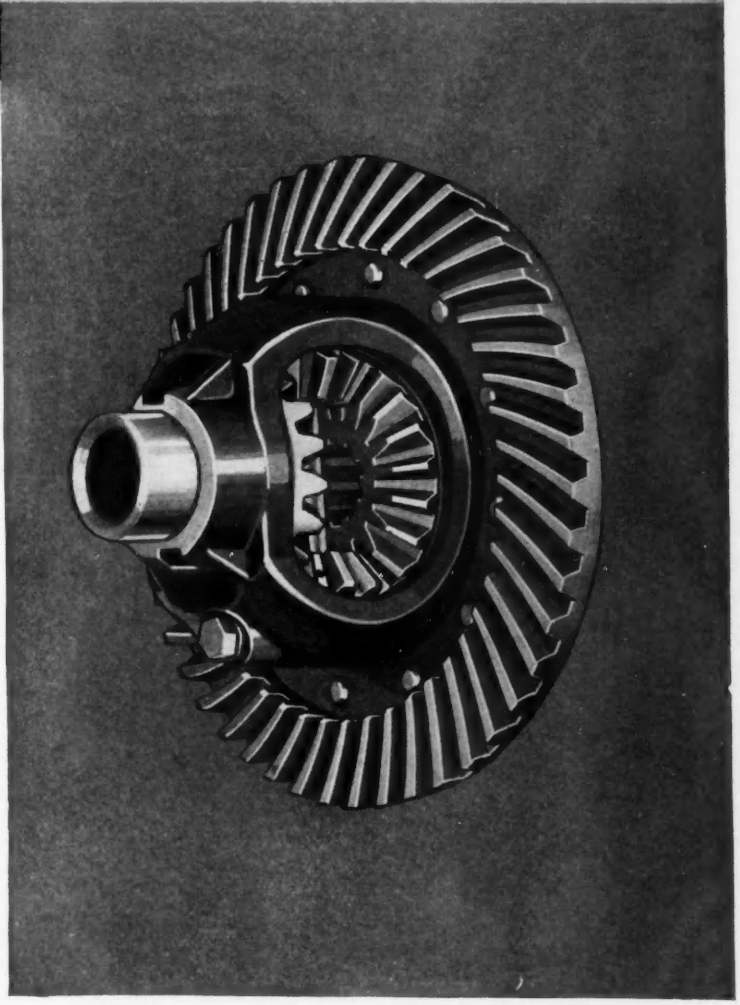

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Notes and Reviews
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The Modern Diesel. Published by Iliffe & Sons, Ltd., London, 1932; 142 pp. [E-3]

This handbook on high-speed compression-ignition engines for road transport, aircraft and marine work treats the subject in elementary style and, in addition to outlining the history of the development of compression-ignition engines and explaining the action of the Diesel cycle, includes descriptions of the various fuel-injection systems.

Compression-Ignition Engines for Road Vehicles. Compiled by the editor of *The Commercial Motor.* Published by the Temple Press, Ltd., London, 1932; 132 pp. [E-3]

This is a manual dealing in a simple manner with the principles of operation and constructional details of all types of oil engine that can be utilized for commercial vehicles or private cars, their accessories, fuels, lubricants and so forth.

MATERIAL

Combustion Velocity of Benzine-Benzol-Air Mixtures in High-Speed Internal-Combustion Engines. By Kurt Schnauffer. Translated from *VDI-Verlag G.m.b.H.*, Berlin, 1931. N.A.C.A. Technical Memorandum No. 668, April, 1932; 17 pp., 20 figs. [G-1]

Flow of Petroleum Lubricating Greases—I. By M. H. Arveson. Published in *Industrial and Engineering Chemistry,* January, 1932, p. 71. [G-1]

This article treats petroleum greases in the restricted sense of a soap-thickened mineral lubricating oil. The author points out that these greases are dispensed and used as lubricants under a variety of conditions in which the factors determining the flow characteristics are of primary importance. A viscometer based on a novel principle, which predetermines the rate of shear and is especially designed for the purpose of measuring the flow characteristics of lubricants, is described.

The data at 77 deg. fahr (25 deg. cent.) on several worked cup greases and a pulp oil are presented in graphical form. The large range of rate of shear reported (0.08 to 132,000 reciprocal seconds) covers the complete practical range of use. Among others, the following conclusion is drawn: The apparent viscosity of greases decreases with increasing rates of shear in a manner characteristic of the particular soap used, approaching in the limit a value higher than, but of the same order of magnitude as, the oil in the grease.

Effect of Casting Temperatures and of Additions of Iron on Bearing Bronze. By C. E. Eggenschwiler. Published in the *Bureau of Standard Journal of Research,* January, 1932, p. 67. [G-1]

A study was made of the effect of different casting temperatures (1850 to 2120 deg. fahr.) and of additions of from 0 to 1.0 per cent of iron upon the hardness and the structure and upon the resistance to wear, pounding and single-blow impact of a bearing bronze containing 80 per cent of copper, 10 per cent of tin and 10 per cent of lead.

In general, increasing the casting temperatures from 1850 to 2120 deg. fahr. increased the resistance to wear, increased the grain size with only a slight effect on the distribution of the lead and slightly decreased the Brinell hardness. The resistance to pounding was increased within the casting range of 1900 to 2000 deg. fahr., and the notch toughness decreased on the bronzes cast close to 2000 deg. fahr.

Additions of iron exceeding 0.3 per cent proved detrimental. Smaller additions of iron decreased the resistance to wear and increased the Rockwell and Brinell hardness. Additions of iron up to 1.0 per cent increased the resistance to pounding. Increasing the iron content above 0.3 per cent produced the segregation of lead particles and decreased the grain size and the notch toughness.

Tests on Tin-Base and Lead-Base Bearing Metals. By C. Jakeman and Guy Barr. Published in *Engineering,* Feb. 12, 1932, p. 200. [G-1]

The research herein reported was made for the Tin Research Subcommittee of the British Non-Ferrous Metals Research Association with the primary object of ascertaining the comparative chemical action of lubricants upon tin-base and lead-base bearing metals.

The results obtained indicate that an alkali metal-lead alloy will run satisfactorily at moderate loads and temperatures when lubricated with mineral oil or compounded oil, but the conclusions drawn from the whole investigation are that, while neither high-

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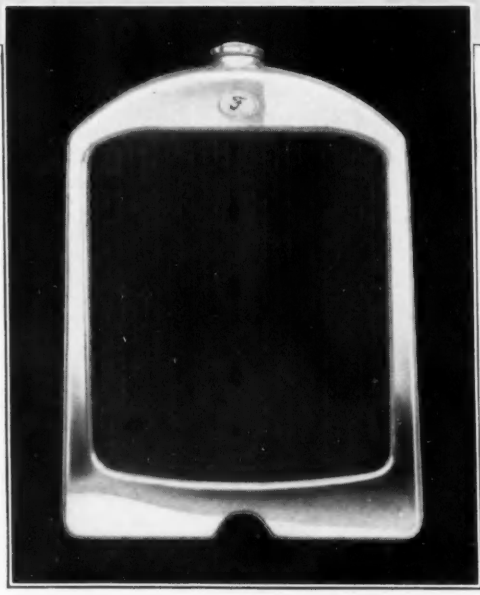

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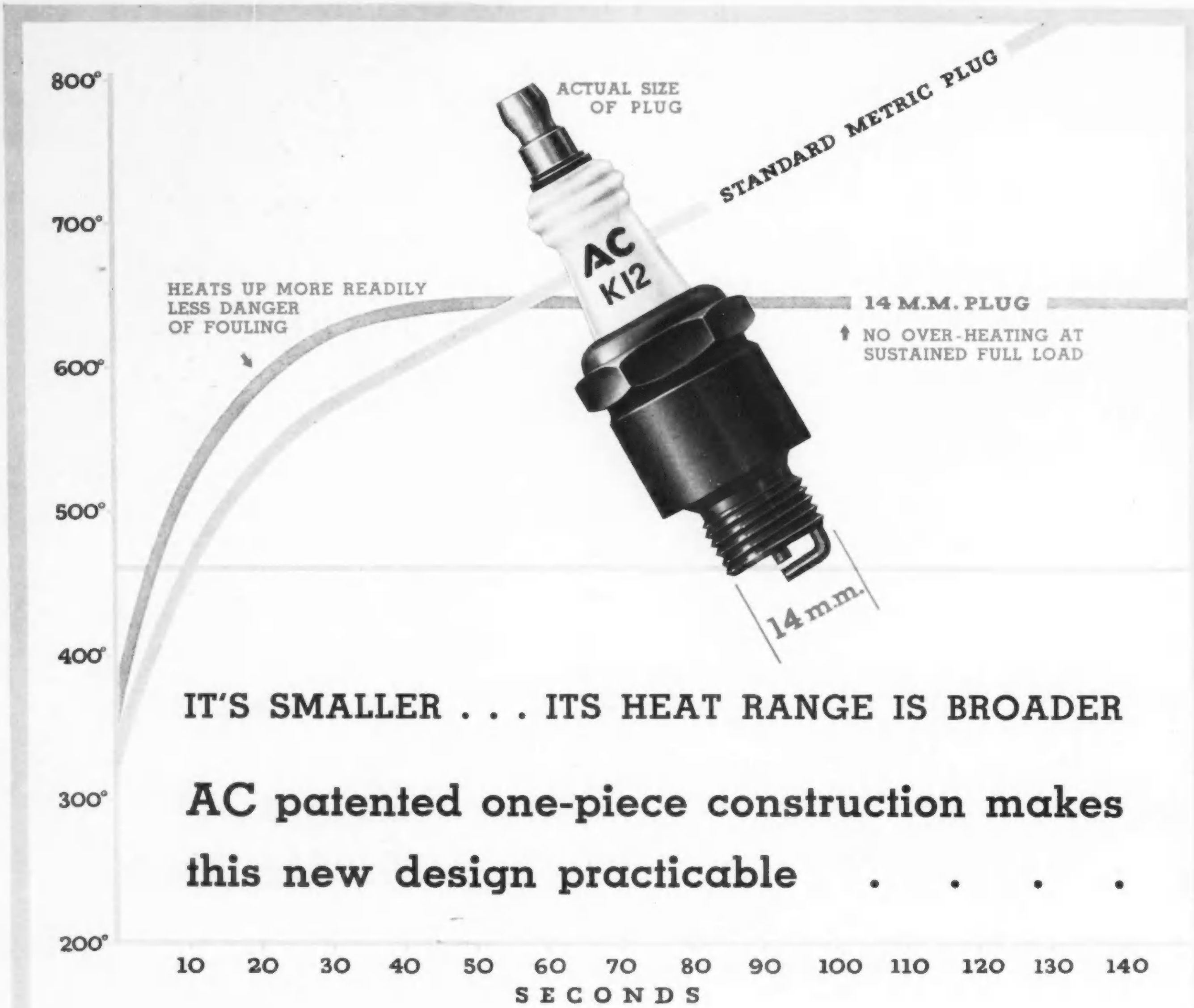

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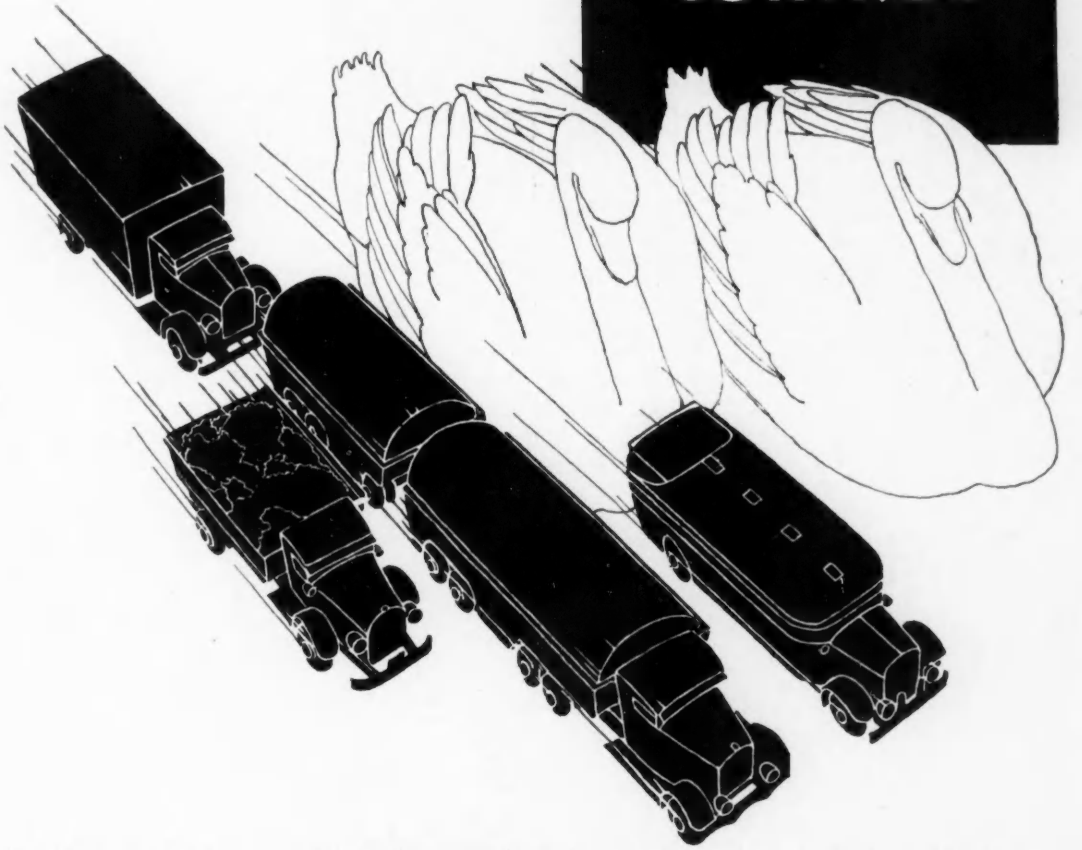
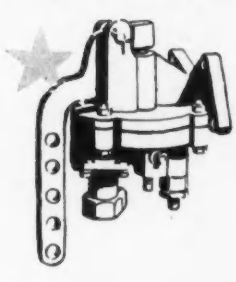
SMOOTH . . *effortless* CONTROL



Smooth, effortless control is more than a feature of modern Automotive Air Brakes. Today, more than ever before, it is a necessity in the safe, efficient operation of the heavy-duty motor vehicle ★ Smooth! Offering a cushioned braking protection to the most fragile cargo . . . Effortless! Permitting the operator to give full attention to his other duties . . . Air Brakes, with power-to-spare, more than justify their ranking as "Safety Standard of the World". Bendix-Westinghouse Automotive Air Brake Company at Pittsburgh, Penna.

BENDIX WESTINGHOUSE

Automotive Air Brakes



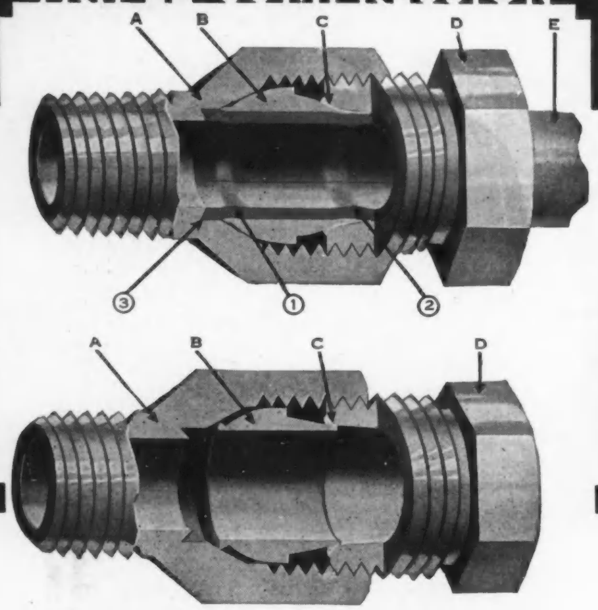
THE BRAKE VALVE
Perhaps the most inconspicuous item of Air Brake Equipment, this ingenius device is directly responsible for the instant, smooth, effortless action of Bendix-Westinghouse Brakes ★ Responsive to even a feather-like touch, at the brake pedal, its rugged dependability reflects the years of engineering research attending its development.

ANNOUNCING

Dole

UNIVERSAL ALL-TUBE COUPLING

TRIPLE COMPRESSION



WITHOUT TUBING – BEFORE COMPRESSION

(1) First Compression (A) Body
(2) Second Compression (B) Sleeve
(3) Third Compression (C) Solder Bearing
Patented February 3, 1931 No. 1,791,121 (D) Nut
(E) Seamed Tubing

Approved by the Underwriters Laboratories

HERE is the result of supreme engineering effort and experience to provide a single type of compression coupling to fit universally all seamed or seamless tubing of steel, aluminum, brass or copper. It is no longer necessary to depend upon couplings of various designs and construction for joining differently constructed kinds of tubing.

This Dole Universal All-Tube Coupling of two piece design surpasses all for joining to seamed or seamless tubing—for safety against leakage—for holding under all strain and vibration—for simplicity of connection—no separate sleeves—no flaring—no soldering—for reconnecting speedily and without limit—*for ultimate satisfaction and economy.*

The coupling consists of only the body and the threaded sleeve screw. Repeated connecting will not reduce the efficiency. Finger turned except for the compression turn. The solder which holds the sleeve on to the nut is sheared off during compression, thus giving a lead lubricated bearing—an exclusive Dole feature.

Our engineering department will be pleased to work with you in the application of Dole Universal All-Tube Couplings. Cut open samples will be sent free upon request.

THE DOLE VALVE COMPANY
1713-33 Carroll Avenue Chicago, Illinois, U. S. A.

Notes and Reviews

Continued

lead nor high-tin alloys are readily attacked by the lubricants in common use, such as mineral oil, compounded mineral oil and castor oil, a higher friction loss generally will occur with a high-lead alloy than with a high-tin alloy.

Protection of Metal Parts of Aircraft against Corrosion. By H. Sutton. Published in *The Journal of The Royal Aeronautical Society*, January, 1932, p. 1. [G-1]

The author reviews the various methods for protecting metal aircraft parts, including: the development of stainless steels; enamels and organic protectives; cadmium-plating; zinc-plating; zinc coating by the hot diffusion or sherardizing method; electrolytic nickel coatings; the protection of steels against oxidation at elevated temperatures by nickel-plating, "calorizing," aluminum spraying and aluminum dipping; the protection of aluminum and aluminum alloys by the use of aluminum as a pigment in enamels and by the use of high-purity aluminum coatings, such as the aluminum-coated duralumin sheet, or Alclad; anodic oxidation or the producing of an oxide film on the surfaces of aluminum and its alloys; and the protection of magnesium alloys by anodic treatment producing a resistant oxide film.

Determination of Tin in Irons and Steels. By J. A. Scherrer. Published in the *Bureau of Standards Journal of Research*, February, 1932, p. 309. [G-1]

Apparently tin is invariably a constituent of irons and steels, usually in amounts ranging from a few thousandths to a few hundredths of 1 per cent. The accurate determination of such small percentages of tin is difficult, and methods that have previously been recommended are unsatisfactory. As a result of the study herein reported, a method has been developed in which tin is separated from interfering elements, such as chromium, vanadium and tungsten, by precipitation as sulphide in a dilute nitric-acid solution and then separated from elements such as copper and molybdenum by precipitation with ammonium hydroxide. These treatments remove the elements that interfere, and the tin is then reduced in sulphuric-hydrochloric-acid solution containing granulated lead and afterward oxidized as usual by a standard solution of iodine. With proper precautions, results that are accurate to 0.001 per cent can easily be obtained.

The Status of Chromium-Plating. By William Blum. Published in the *Journal of the Franklin Institute*, January, 1932, p. 17. [G-1]

This summary of the present status of chromium-plating makes no attempt to consider the details of the process but aims to give a bird's-eye view of the methods and applications and especially the limitations and probable future uses.

The author points out that, parallel with the increasing use of chromium, a marked development of chromium-alloy steels, for example, of the stainless type, has occurred. At present these two methods of obtaining a lustrous, tarnish-resistant surface are in direct competition, particularly in the automobile industry. Some of the factors that undoubtedly will influence the final choice are discussed.

Tin—World Statistics, 1932. Compiled and published by the Anglo-Oriental Mining Corp., Ltd., London, 1932; 137 pp. [G-5]

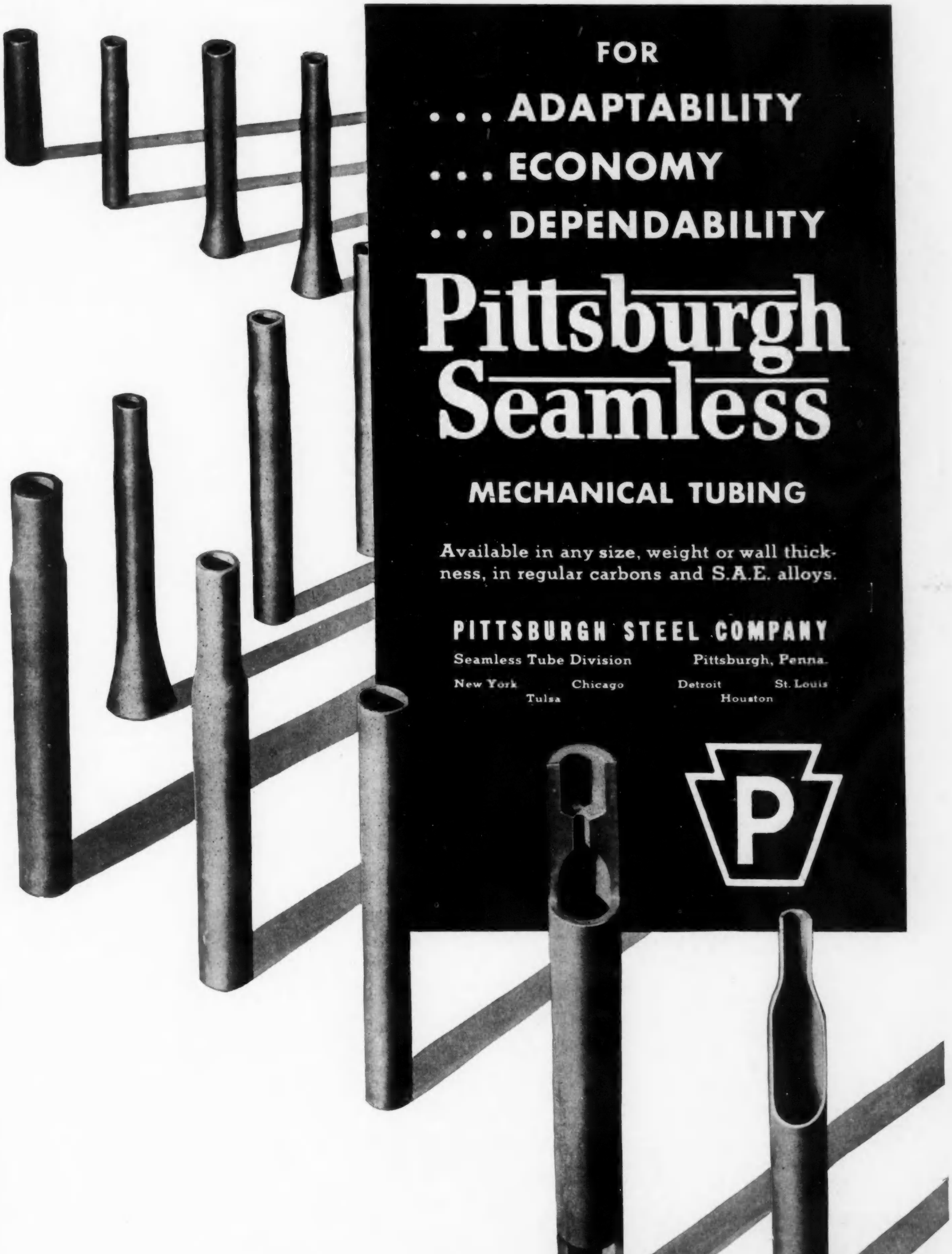
Statistics regarding the production, consumption and stocks of tin, together with tables showing the history of price changes, are compiled and tabulated in this book, which is an outgrowth of the work of the International Tin Committee organized early in 1931 to formulate an international scheme, having as its object the statutory regulation of the production and export of tin in each of the principal tin-producing countries of the world.

Beryllium—Its Production and Application. Compiled by Zentralstelle für Wissenschaftlich-Technische Forschungsarbeiten des Siemens-Konzerns. Translated by Richard Rimbach and A. J. Michel. Translation published by the Chemical Catalog Co., Inc., New York City, 1932; 331 pp. [G-5]

This book contains reports devoted exclusively to beryllium, its production and use. It is a comprehensive report of the work on the subject of beryllium carried out since 1923 at the Siemens-Konzern. Those whose names appear in the long list of collaborators are also the authors of the reports.

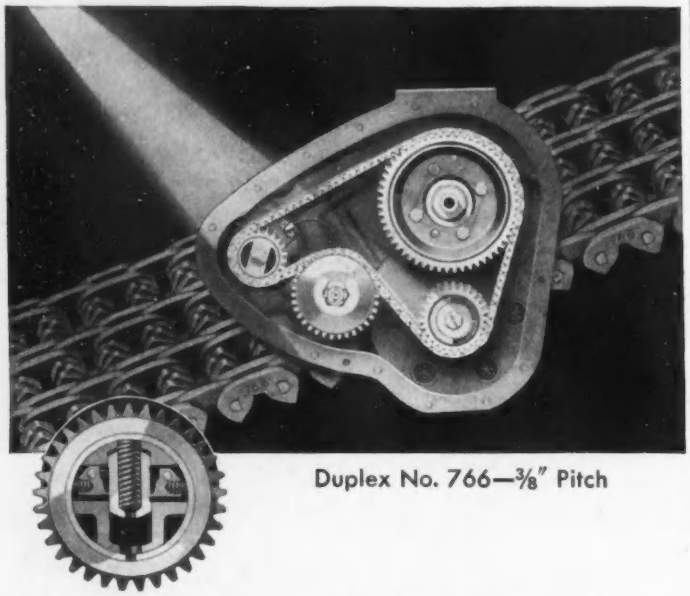
The research program included the following: (*a*) further improvements of the electrolytic methods; (*b*) development of a satisfactory analytical method for detecting beryllium in the raw material and in alloys, and determination of the degree of purity of the beryllium metal obtained; (*c*) development of economical processes for producing the beryllium salts required for the electrolytic method from the raw beryl; (*d*) investigation of the

(*Concluded on next left-hand page*)



FOR
. . . ADAPTABILITY
. . . ECONOMY
. . . DEPENDABILITY
Pittsburgh Seamless
MECHANICAL TUBING
Available in any size, weight or wall thickness, in regular carbons and S.A.E. alloys.
PITTSBURGH STEEL COMPANY
Seamless Tube Division Pittsburgh, Penna.
New York Chicago Detroit St. Louis
Tulsa Houston
P

20 YEARS OF SPECIALIZATION



Duplex No. 766—⅜″ Pitch

Twenty years of specialization in the design, development and refinement of Morse Timing Chain front end drives, have produced many outstanding improvements, among which is numbered the Morse Automatic Adjustment.

This feature, together with the Morse ⅜″ pitch type 766 Duplex Chain, is embodied in such distinguished cars as the Cadillac V-12 and V-16 and the Lincoln V-12.

Points of special advantage in this improved automatic adjustment are: (1) the radial action of its floating bronze carrier; (2) the compression springs of even tension; (3) the hardened steel sprocket, rotating on bronze—all features which insure lifetime service.

Further data and design suggestions upon request

MORSE CHAIN COMPANY
Ithaca, N. Y.; Detroit, Mich.
Division of Borg-Warner Corporation
Morse Chain Co., Ltd., Letchworth, Herts, England

MORSE EQUIPPED PASSENGER CARS

American
CADILLAC V-8
CADILLAC V-12
CADILLAC V-16
CHRYSLER 6
CHRYSLER 8
CHRYSLER 8 DE LUXE
CHRYSLER IMPERIAL 8
CONTINENTAL MOTORS
DE SOTO 6
DE VAUX 6-80
DODGE 6
DODGE 8
DURANT 6 (619)
ESSEX 6
HUDSON 8
HUPMOBILE 8-221
HUPMOBILE 8-225
HUPMOBILE 8-226
HUPMOBILE 8-237
HUPMOBILE 8-218
LA SALLE 8
LINCOLN 8
LINCOLN V-12
A manufacturer of high grade eights (Name on request)
PEERLESS 8 (Custom)
PEERLESS 8 (Master)
PONTIAC 6
REO FLYING CLOUD 6
REO FLYING CLOUD 8
REO ROYALE 8
ROCKNE 6-65

Foreign
ADLER
BRENNABOR
FIAT
VAUXHALL
WANDERER WERKE
ZSCHOPAUER

MORSE
GENUINE *SILENT* CHAINS

Notes and Reviews

Concluded

properties and application possibilities of pure beryllium; (*e*) investigations into the alloying properties of beryllium with other light metals, as well as the properties of such alloys; (*f*) investigations into the alloying properties of beryllium with heavy metals and the properties of such alloys; (*g*) studies of the occurrence of raw beryl; and (*h*) development of a reliable supply of raw beryl.

MISCELLANEOUS

Depression and Unemployment—Why? By Adolph Moses. Published by the author, 46 Washington Square South, New York City, 1932; 19 pp. **[H-3]**

The author describes himself as "a mechanical engineer, inventor and designer of labor-saving and power-generating machinery and a skilled mechanic, who has received most of his relatively small income from wages". Inability to find work led him to study the economic situation, in the hope that he might be able to determine what practices had brought on the depression, and to make it possible to recognize and correct the faults so that industry might again increase and absorb some of the unemployed.

His analysis of the causes of business inflation and deflation is presented in simple terminology, and, while comprehensive in its scope, is concise in form.

Dr. Sperry as We Knew Him. Compiled by the Japanese Memorial Book Committee. Japanese section edited by Zenichi Kawaguchi; English section, by Russell L. Durgin. Published by the Nichi-Bei Press, Yokohama, 1931; 477 pp. **[H-3]**

To the late Elmer A. Sperry's countless friends all over the world who read this book must come a feeling of gratitude to the group of prominent men in Japan who have collaborated in the preparation of this splendid portrayal of Dr. Sperry's life, character and work.

Dr. Hideo Takeda, chairman of the Memorial Book Committee, explains in the foreword that

> Since it was not the intention of the committee to produce any regular biographical sketch of his life, we have recorded neither the details of his wonderful inventions nor a minute account of his achievements. The aim of the volume has been to state the relation and merits of his ideas and works as they have affected our country, and his character and personality as it is reflected in the eyes of his Japanese friends. It was only to define Dr. Sperry "as we knew him," and in one sense the work may be said to be but a simple collaboration of reminiscences growing out of his connection with Japan.

Dr. Takeda further states that in Japan, besides Dr. Sperry's renown as an engineer, inventor and philanthropist, "we revere him as a sincere and sympathizing friend of our country."

PASSENGER CAR

The Gasoline Automobile. By Ben G. Elliott and Earl L. Consoliver. Published by the McGraw-Hill Book Co., Inc., New York City and London; fourth edition, 1932; 605 pp., illustrated. **[L-3]**

Since the first edition was brought out in 1915, this work has had a total issue of 113,500 copies; therefore, it is sufficient to state that in the new edition the authors have adhered to the primary objective of presenting a textbook for the teaching and study of the fundamental principles and ideas upon which the modern motor-vehicle is designed, constructed and operated.

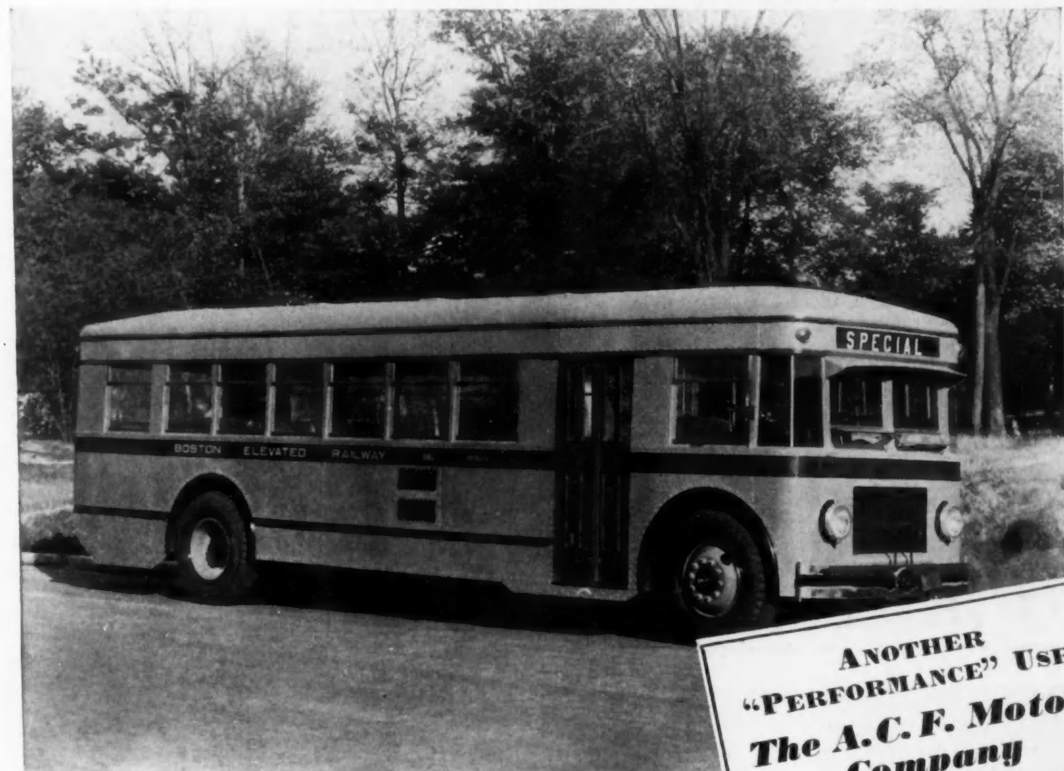
In each succeeding revision, Professor Elliott has brought the text to the new levels of the changing times. The present revision, therefore, not only brings the technical and mechanical developments uptodate, but takes account of the general social and economic setting.

Gasoline Automobiles. By James A. Moyer. Published by the McGraw-Hill Book Co., Inc., New York City and London, fourth edition, 1932; 509 pp. **[L-3]**

The purpose of the author is to present clearly and briefly the essential principles of automobile construction and operation, with the expectation of furnishing practical help to drivers who wish to undertake their own repair work.

In the present edition, the book has been extensively rewritten, all of the pages have been reset, and many new illustrations added. All of the important improvements that have been introduced within recent years are included, and other related topics such as detonation, turbulence, hydrogenation, vapor lock and humidity effects on engine power are treated.

MILEAGE RESULTS ASSURED WITH SKF ECONOMY



ANOTHER "PERFORMANCE" USER
The A.C.F. Motors Company

WHERE PERFORMANCE TAKES PREFERENCE OVER PRICE

STARTS AND STOPS... they're quite frequent in the heavy duty service this A.C.F. H-7 Metropolitan All-Steel Coach meets in city traffic daily. And this sort of operation certainly puts some pretty gruelling demands on the clutch pilot bearing. The SKF Bearing used for this location clearly demonstrates that SKF Performance Takes Preference Over Price.

There is an ample reserve of stamina in every SKF Bearing which assures long life service at the lowest cost per bearing mile. SKF Bearings are free from wear and never require adjustments. These two features insure smooth, quiet operation with a minimum of maintenance and the elimination of schedule interruptions from bearing failure... important considerations where bus operating costs must be kept at the lowest possible level.

You may buy a bearing as a bargain but try and get a bargain out of using it, for nothing is apt to cost so much as a bearing that cost so little.

2889

SKF INDUSTRIES, INC. 40 EAST 34th STREET, NEW YORK, N. Y.

SKF

Ball and Roller Bearings

Personal Notes of the Members

(*Concluded from p. 25*)

to receive various awards from the institute for their accomplishments in sciences and the mechanical arts.

Edward V. Rickenbacker, having resigned as vice-president and director of sales of the General Aviation Mfg. Corp., of New York City, was recently elected vice-president of the Aviation Corp., also of New York City.

P. B. Rogers was recently elected vice-president in charge of engineering and also a member of the board of directors of the Great Lakes Aircraft Corp., of Cleveland. His previous position was that of chief engineer of the corporation.

George T. Rolan has been appointed supervisor of company service stations for the Rusk-Lehigh division of the Vacuum Oil Co., Inc., at Allentown, Pa. His former connection was with the Cadillac Motor Car Co., in Brooklyn, N. Y., as owner-contact man.

Herbert Scheel is now in the sales engineering department of the Zenith Petroleum Works, of Dallas, Tex. He was formerly sales engineering manager of the Superblend Petroleum Corp., of Dallas.

Alois H. Schmal, having relinquished his position as executive engineer with the International Motor Co., at New Brunswick, N. J., is now connected with the S K F Industries, Inc., of New York City, and is in charge of the automotive division of the engineering department.

Adolf G. Schneider, who was chief designer of the J. H. McCormick Co., of Williamsport, Pa., is now connected with the Northern Pump Co., of Minneapolis.

A. R. Smythe, formerly sales manager of the Imperial Oil Co., Ltd., of Toronto, Canada, has been appointed manager of the company's motor equipment department.

Curtis C. Stewart has relinquished his transportation-engineering connection with the Lapeer-Trailmobile Co., of Chicago, and is now general manager of the Cartage Exchange of Chicago, an association of motor-truck operators of that city.

C. W. Stratford, who used to be manager of the Stratford Engineering Co., of Kansas City, Mo., has established in Paris and is at the head of the Alco Products International, formed for the purpose of selling petroleum-refining equipment in Europe.

P. S. Vail, formerly general superintendent of transportation for the Langendorf United Bakeries, of San Francisco, is now superintendent of transportation for the Old Homestead Bakery, of the same city.

James S. Watson, vice-president of the Link-Belt Co., in charge of the company's Dodge Works in Indianapolis, has been made vice-president and general manager of the company's two chain factories in that city—the Dodge and the Ewart Works.

Theodore A. Wells, who was project engineer of the Curtiss Wright Airplane Co., of Robertson, Mo., has been appointed chief engineer of the Beech Aircraft Co., of Wichita, Kans.

Gilbert A. Worrall, formerly manager of the New Zealand division of the White Motor Co. at Wellington, is now manager of the Albany, N. Y., branch of the company.

Don't Forget

S. A. E. Summer Meeting

June 12-17, 1932

White Sulphur Springs, W. Va.

See p. 13 for complete program

Quick Starts

and many of them

Willard STORAGE BATTERIES

B. C. A. Angular Contact and Thrust Bearings

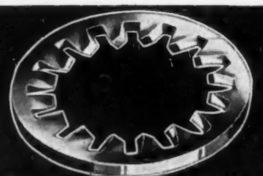
B. C. A. Angular Contact Bearings render unusual service in the clutch throwout under increased loads occasioned by Free-wheeling and automatic controls.

Bearings Company of America
Lancaster, Penna.
Detroit, Mich. Office: 1012 Ford Bldg.

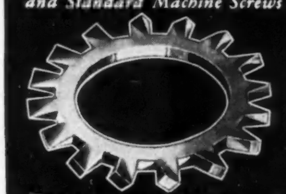
SHAKEPROOF

Don't cheat yourself

by using INFERIOR lock washers



Type 12. *Internal. For S. A. E. and Standard Machine Screws*



Type 11. *External. For Standard Bolts and Nuts*

Type 15. *Countersunk. For all Countersunk Screws*

Type 20. *Locking Terminals. For Radio and Electrical Work*

U. S. Patents
1,419,564—1,604,122
1,697,954—1,782,387
Other Patents Pending. Foreign Patents.

YOU cannot judge the value of lock washers by figures — it's performance that counts. That's why leading manufacturers, who know what Shakeproof protection means, refuse to consider any cheap inferior substitute for their products. They have learned by years of experience that the patented twisted teeth of this dependable lock washer provide an absolutely tight connection which vibration cannot budge.

Give your product a chance—specify Shakeproof Lock Washers under every nut and screw. It will mean improved performance, less service expense and greater customer good will. If you doubt this, send for testing samples today and see the difference with your own eyes. Mail the coupon now!

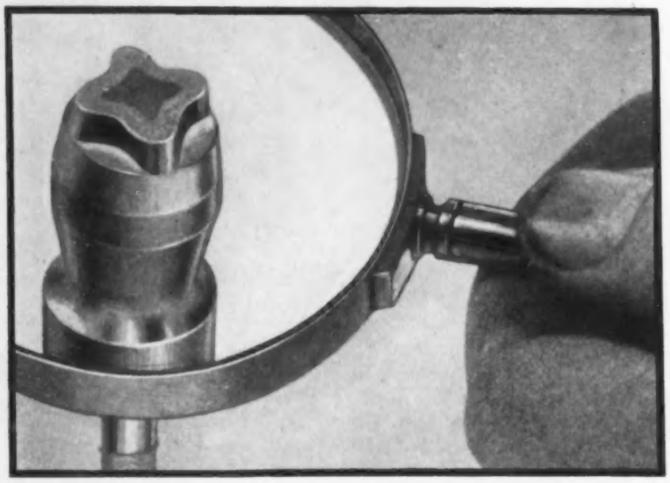
Shakeproof Representatives are located in the following cities:
New York City Philadelphia Boston
Pittsburgh Schenectady Milwaukee
Detroit Toledo Cincinnati Cleveland
Birmingham, Ala. Dallas, Texas
Seattle Los Angeles San Francisco
Toronto, Ontario, Canada

SHAKEPROOF
Lock Washer Company
{Division of Illinois Tool Works}
2507 North Keeler Avenue Chicago, Illinois

COUPON Gentlemen: We want to test your Shakeproof Lock Washers. Kindly send us samples as indicated.

Type.................... Size....................
Type.................... Size....................
Firm Name....................
Address....................
City.................... *State*....................
By.................... *Title*....................

HAD SWEDGED TERMINALS



The actual photo, above, of the new HAD Swedged Snap Terminal . . . (enlarged six times) . . . clearly shows how tightly the copper wires and the brass portion of the terminal are SWEDGED together . . . at the top!

In fact, the top is one solid piece of metal . . . with only a difference of color showing where the copper and brass meet!

Here is the perfect, non-corrosive, solderless and economical Swedged Snap Terminal! For we furnish the full equipment for Swedging! Just drop us a line and we'll gladly tell you all about them!

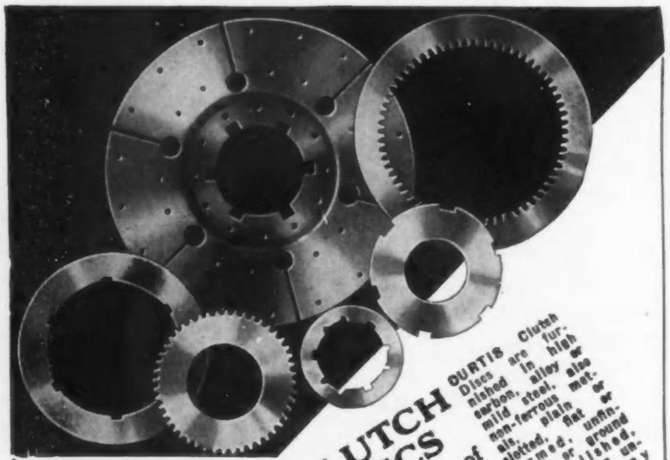
HAD H. A. DOUGLAS MFG. CO. HAD
BRONSON, MICH.

YOUR TUBING PROBLEM?

Have you an infrequent operation—or a too costly part—or need a new design? Perhaps we can find your answer. Get our prices—on lengths, coils or fabricated parts.

WOLVERINE TUBE CO.
SEAMLESS COPPER BRASS & ALUMINUM
1445 Central Ave. Detroit, Mich.

Sales Offices: Cleveland; Chicago; Atlanta; Los Angeles; Denver; Dayton, Ohio; New York City; Dallas, Texas



CURTIS CLUTCH DISCS

CURTIS Clutch Discs are furnished in high carbon, alloy or mild steel, also non-ferrous metals, plain or slotted, flat or formed, unfinished or ground and polished, tempered or untempered, any size.

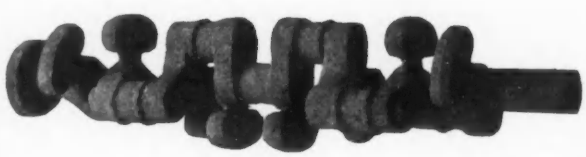
Only long experience in the manufacture of Clutch Discs can tell a manufacturer what is necessary for satisfactory performance in automobile, truck or tractor service.

This company has concentrated its efforts for years on the manufacture of custom-built Clutch Discs of precision. The result of that skilled experience shows in the perfection of its finished product.

And because of solving so many perplexing problems in this field, the Curtis Company is particularly qualified to give expert advice as to your particular needs. Correspondence is invited.

CURTIS CLUTCH DISC CO.
Division of Curtis Manufacturing Company
1956 Kienlen Ave.
St. Louis, Mo.

Counterbalanced



Crank Shafts

AND

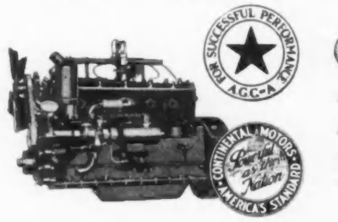
HEAVY DIE FORGINGS

The Park Drop Forge Co.
Cleveland, Ohio

"EXPERIENCE ESSENTIAL . ."

When you have a big job to be done, you go after an experienced man to do it. An engine does the work of many men. That is why you should say "experience essential" when you buy one.

Continental has produced more than 3,000,000 engines in the past 30 years. They have worked on every conceivable type of job. Experience is the fundamental reason for the excellence which characterizes every Continental engine. You can benefit by this thorough knowledge of many jobs in many fields by specifying Continental.



The name "Continental" is synonymous with the word "experience." It guarantees real performance and a dependable, economical source of supply.

Continental Engines

Continental Motors Corporation, Detroit, Michigan

UPHOLDING QUALITY ATLAS

for Engineering Aid

ATLAS DROP FORGINGS

While your drop forgings are still on paper, that is the time to insure economical production. Call in Atlas men for assistance in design and metallurgical specifications. They will show you specific examples of savings made for others and may find some way to lower your machining costs.

ATLAS DROP FORGE CO.
LANSING • MICHIGAN

ENDURO

REPUBLIC'S PERFECTED STAINLESS STEEL

Not too expensive for the lowest priced car, yet fine enough for the most distinctive custom made body. ENDURO, Republic's Perfected Stainless Steel, brings permanent beauty that is reflected in increased sales.

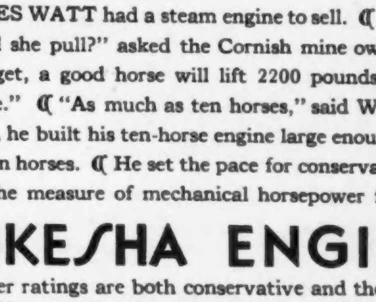
For Literature Write to

CENTRAL ALLOY DIVISION
MASSILLON, O.

REPUBLIC STEEL CORPORATION

GENERAL OFFICES YOUNGSTOWN, OHIO

The First Steam Engine



JAMES WATT had a steam engine to sell. ("How much will she pull?" asked the Cornish mine owner. "Don't forget, a good horse will lift 2200 pounds of coal 100 feet a minute." ("As much as ten horses," said Watt. (And, to make sure, he built his ten-horse engine large enough to do the work of fifteen horses. (He set the pace for conservative ratings, and he set the measure of mechanical horsepower for all time.

WAUKESHA ENGINES

. . . All power ratings are both conservative and thoroughly dependable. *Write* for Bulletin 827, *Waukesha Motor Company, Waukesha, Wisconsin.*

REAL HORSE POWER NOT PAPER HORSE POWER

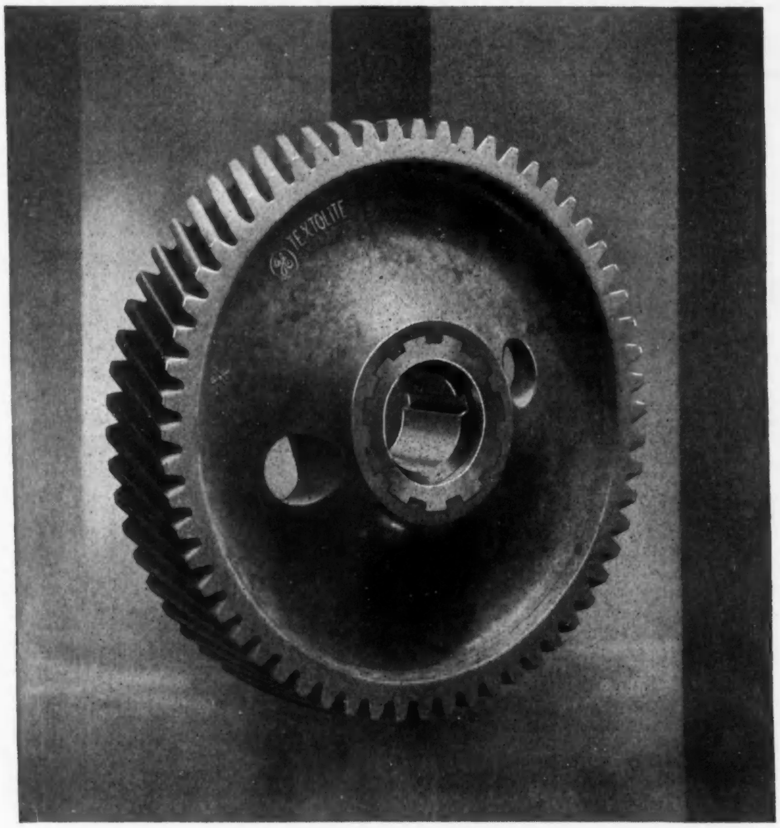
Index to Advertisers' Products

(Continued on page 50)

Manufacturers of Products Conforming to S.A.E. Specifications

Advertisers whose products conform to S.A.E. specifications are also listed in the S.A.E. Handbook List of Manufacturers, beginning on page 675, of the 1931 issue of the Handbook.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 52.



Gear Timing Is the Simplest

THE best design is the simplest. The fewer the parts, especially if moving, the greater the reliability, the less the wear.

The nonmetallic-gear timing drive consists simply of a gear on the camshaft meshing with another on the crankshaft—sometimes with a second on the auxiliary shaft. No simpler design is conceivable.

This simplicity of design combined with the extraordinary lightness, resilience, and wearing qualities of the nonmetallic gear results in precise, permanent timing at low cost.

TEXTOLITE
TIMING
GEARS

830-106

GENERAL ELECTRIC

INDEX TO ADVERTISERS' PRODUCTS

SPRING ENGINEERING

Spring design calculated to do safely the things required the way you need them done.

«Two Plants for Spring Service»

BGR INC.

COOK SPRING CO. DIV.
ANN ARBOR, MICHIGAN

DETROIT DIVISION
6400 MILLER AVENUE

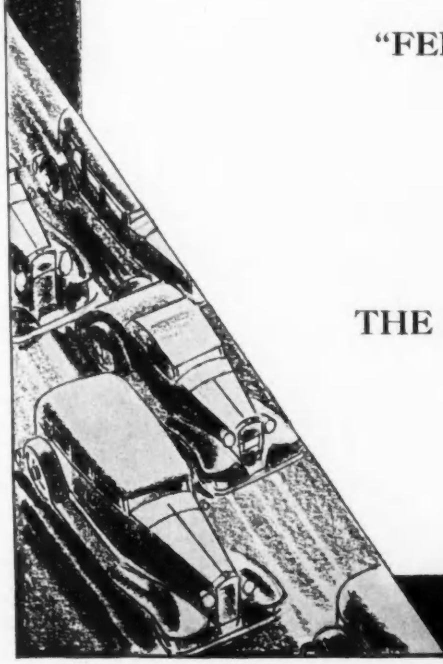
BARNES-GIBSON-RAYMOND-INC

FEDERAL BEARINGS

SELECTED by automotive manufacturers who seek only the highest standards of ball bearing excellence.

Neither time, money, nor labor are spared to make "FEDERALS" the finest bearings that human skill and modern machines can devise.

"FEDERALS" *are made in a large, modern and splendidly equipped factory.*



THE FEDERAL BEARINGS CO., INC.
POUGHKEEPSIE, N. Y.

Detroit Sales Office: 2608 Book Tower
Chicago Office: 120 N. Peoria St.

INDEX TO ADVERTISERS

The Index to Advertisers' Products is given on pages 48 and 50

THOUSANDS

OF AUTO-LITE SERVICE STATIONS

ready to give dependable service

OFFICIAL AUTO-LITE SERVICE

In the past 21 years, millions of automobile owners have come to rely on the always dependable Auto-Lite service stations. They know that in whatever part of the country they may be, prompt and courteous attention to their needs is ever available.

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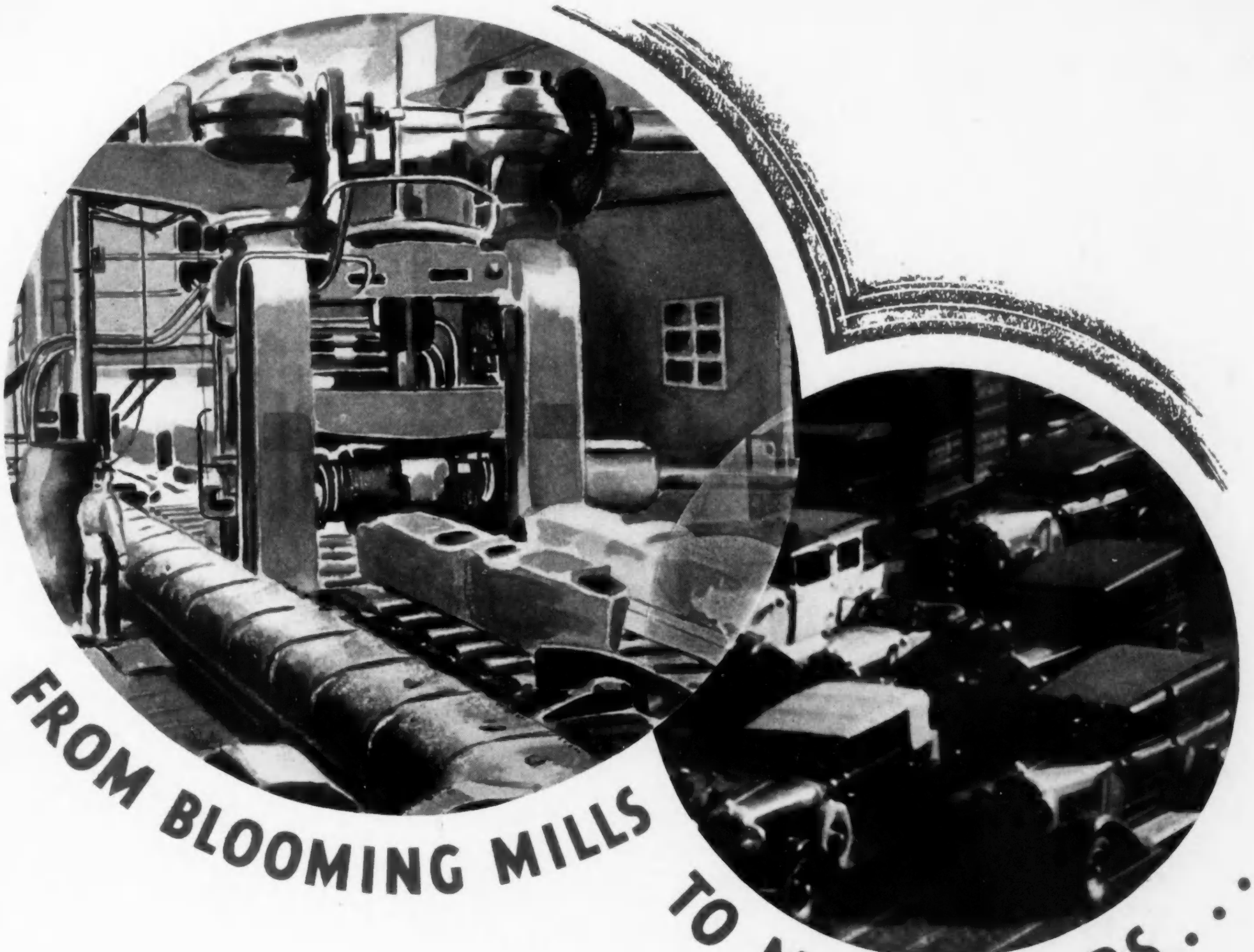

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